

1177# 5418 ⁵⁰/_c 86-

THERMOMETRICAL NAVIGATION.

BEING
A Series of Experiments and Observations,
TENDING TO PROVE,
THAT BY
ASCERTAINING
The RELATIVE HEAT *of the* SEA-WATER
FROM TIME TO TIME,
The Passage of a Ship
THROUGH
THE GULPH STREAM,
AND
FROM DEEP WATER INTO SOUNDINGS,
May be discovered in Time to avoid Danger,
ALTHOUGH (OWING TO TEMPESTUOUS WEATHER,)
IT MAY BE IMPOSSIBLE
To heave the Lead or observe the Heavenly Bodies.

Extracted from the American Philosophical Transactions, Vol. 2 & 3;

WITH
ADDITIONS AND IMPROVEMENTS.

"God helps them that help themselves."

Poor Richard.

PHILADELPHIA:

PRINTED AND SOLD BY R. AITKEN, No. 22, MARKET STREET.

1799.

THE PATENT OFFICE
LIBRARY

A Series of Experiments and Observations

on the

Properties of the

of the

of the

of the

of the



THOMAS TRUXTON, Esq.



COMMANDER

OF THE

American Frigate

CONSTELLATION.

Dear Sir,

THE experiments which induced me to believe that the thermometer might become a valuable nautical instrument to discover soundings having been first made on board of a ship under your command, the following performances have a natural claim to your patronage; and if the proposed method should be practised on board of the Constellation, your example would doubtless stimulate other navigators, and bring it into general use.

The

The public voice, for obvious reasons, point you out as a character to whom American Improvements in Navigation ought to be dedicated; and I am prompted by personal considerations to embrace this opportunity of testifying the high sense I entertain of your patriotism, spirit and talents; as a firm friend to your country, a gallant officer, and skilful navigator.

I am with great regard,

Dear Sir,

Your sincere friend and

Obedient servant,

JONATHAN WILLIAMS.

PHILADELPHIA, August 14, 1799.

INTRODUCTION.

INTRODUCTION.

THE following memoirs may be little known where they originated, owing perhaps to their appearing among a number of transactions which form a volume too bulky to be in many hands. One of them however has had better success in Europe, having been favorably received in England, and translated at Petersburg and Madrid into the Russian and Spanish languages: The latter publication was preceded by a report made by the Director of the Marine Academies in Spain, a translation of which is hereto subjoined.

The present respectable state of the American Navy, both warlike and commercial, induces the author to publish what he has written on this subject, together with the concurrent testimony of others, in one point
of

vi INTRODUCTION.

of view, in hopes that it will be found, on experience, that our coast may be approached with confidence although soundings cannot be obtained, nor the land be seen; and, consequently, that errors in reckoning, may be corrected before danger is near; when (owing to tempestuous weather) it may be impossible to heave the lead, or observe the heavenly bodies. The use of the thermometer in navigation, becomes doubly important, when it is considered that the course towards America is generally westward; so that the corrections of latitude by observation do not determine the distance a ship has to run; and lunar observations are too difficult to be generally understood, even if the moon could be always seen.

Every mariner, when near the coast, feels the importance of speaking a ship from the place to which he is bound; that he may correct the longitude of a long reckoning; by that of a very short one, which cannot be materially wrong if well kept; by this he is enabled to judge of the bearings and distances of the land, and to shape his course accordingly. This is exactly the office the thermometer performs; for it declares by a sudden fall of the mercury, the time when the ship comes into the water between the Gulph Stream and the coast, and, by a further fall, it declares the time when she comes within soundings. In this situation there is, generally,

*the ship speaks northwards twelve
thowards the distance of soundings
as the steam may move to*

twelve hours safe run; so that instead of standing off for fear of being too near in the night, the navigation may be pursued as safely as if the lead could be kept going, with the land in view. In the several instances mentioned, of ships being a-head of their reckonings, they ought not to be understood as implying any reproach to the Captains; for in sailing along the eddy of the Gulph Stream, or in any other current, in an east or west direction, no navigator can expect to be accurate by dead reckoning; since currents can not be ascertained in the usual way, unless the sea be smooth, and that rarely happens. The Captains mentioned in the course of the following observations were skilful navigators, and prudent men; but the more liable the best calculators are to err, the more ought we to value any discovery which tends to determine the distance of danger, before a ship is too near to avoid it.

It has been intimated in one of the following memoirs, that the cause of this difference in the heat of ocean and coast water, may arise from the conducting power of rocks, &c. under water. As the subject is now resumed, it may not be amiss to add some reflections on the substance of that part of the globe, which forms the bottom of the sea.

We are only acquainted with the shell, the mere scarf-skin of the earth, and the sea appears to all human

man efforts fathomless; for it is very probable that after sounding to a certain depth, the line floats the lead. This supposition may serve to explain a phenomenon mentioned by Captain Ellis, and related by Don Cipriano Vimercati, in the annexed report. After sounding to the depth of 3900 feet, Captain Ellis found his thermometer to mark 53° , and when he had 5346 feet of line out, it marked the same degree: Is it not likely that 5346 feet of line, (to which the water must offer some resistance in its descent) would overcome the weight of the lead? Besides, Is it not reasonable to suppose that water at a great depth is more dense than at the surface, and consequently more buoyant? For although water is understood to be incompressible by the weak means in our power, it cannot be so considered by the natural laws of gravity. In this case the sea gauge might be carried horizontally, draw out more line, and be always in the same temperature.

As far as we have gone by digging, and as far as we have been able to penetrate into caverns, the temperature is neither more nor less than 52 or 53, varying only as the instruments may be supposed to differ from each other. This is the state of the thermometer under the observatory at Paris, and in the subterraneous places that have been examined in this country. This is not the case in those places at sea, where bottom can be reached with a lead. The water at the surface over the banks
of

of Newfoundland, is known by experiment to be 47° in *summer, and it is also known by experiment in summer, that at the depth of only 46 fathoms the entrails of a Cod fish is at $\dagger 37^{\circ}$ and 16° colder than the water at the surface.

From analogy, then, it seems, that the banks of Newfoundland, at the bottom, may be considered nearly as cold as ice. But let us suppose a depth many times farther than ever was reached with a lead, and that the banks, descend below their summit, as far as terrestrial mountains rise above their base; why may not this bottom be ice? Water in its natural state is ice, and every thing that can be made liquid, by the communication of heat, will return to its state of solidity, by the privation of it; hence it has been found by circumnavigators, that the Poles are inaccessible on account of their perpetual congelation; so it is found at the top of the highest mountains, where heat cannot be generated by the reverberation of the sun's rays, that the earth is in a state of perpetual congelation.

The influence of the sun on the surface of the Globe, as we have already seen, is limited; and as it penetrates into the matter of the Globe, it grows weaker and weaker. May we not then suppose a depth where it

B

must

* See the annexed chart.

† See appendix, No. 5.

must cease? If so, is it unreasonable to suppose a depth where the sea would be ^{below} at 32° ? and ^{may} ~~must~~ not that be ice? why, it may be asked, is the temperature of the earth and sea, out of soundings, so uniform at a certain depth, both being permanently 53° ? As to the earth such as the surface generally is, it may be answered, that it is not a very ready conductor of heat; and therefore, may retain the heat at a certain depth, beyond which human efforts cannot reach, and which is comparatively, only fkin deep. As to the sea; heated water is lighter than cold, and heat therefore communicates downwards but slowly; though as water is a better conductor than common earth, it may go to a greater depth; but as it grows gradually weaker, it must somewhere cease in the fathomless ocean. This is not the case in soundings, for on the supposition that the banks and rocks are seated on the central matter of the Globe, which may be supposed to be at least as cold as ice, we have a complete conductor continually robbing the circumjacent water of its heat. Rocks and sand it will be remembered, are powerful conductors of heat; more so than water, and much more so than earth, commonly so called, hence it is always found, that after coming within banks, head lands, capes &c. (where there is generally a muddy bottom,) the water is always warmer than on the outside of a bar. This does not affect the principle of thermometrical navigation, as the land in such cases is generally in sight,

fight, and if not, the navigator, by previous observation, must know where he is: It is on the contrary a corroborating proof of the accuracy of a reckoning; for *this inside* muddy bottom will be expected after gaining the coast.

Much has been written about subterraneous fires, which apparently contradict the hypothesis here attempted; but from all we know of them, they may be seated much higher than the banks of the ocean. These fires may be considered as the effect of a chemical combination in Nature's laboratory; and until the combination takes place, the combustible matter may be cold. It is easy to conceive that powder may be made as cold as flint and steel can be, though it only requires collision to produce a spark, and a spark to produce an explosion; and who does not know, that very cold quick lime, mixed with very cold water, would soon produce a very hot substance. Whenever therefore, such combinations happen, an earthquake, or an irruption must follow; for fire in an active state cannot be confined; and until it becomes active, the heat will not be generated. May we not therefore conclude, that the existence of such matters as produce subterraneous fire, is not incompatible with the conjecture that the bottom of the sea is ice. Is not Hecla a burning mountain, and is it not in Iceland?

xii I N T R O D U C T I O N .

The foregoing observations have been written with sentiments of great deference and respect for the opinions of many learned men, which they apparently contradict; but as many of these opinions are diametrically opposite to each other, the field of conjecture is still open: It is a common soil, which every one has an equal right to cultivate, and the writer has entered it with diffidence. He asks the reader's indulgence and candour for whatever he cannot approve, but he makes no claim to his belief, till it shall be justified by time and experience.

JONATHAN WILLIAMS,





EXTRACT
FROM THE
MARITIME OBSERVATIONS
OF
DOCTOR FRANKLIN,
Relative to the GULPH STREAM—Published in the second
Volume of the AMERICAN PHILOSOPHICAL TRANSACTIONS. Page 315.

Dated at Sea, on board the London Packet, Capt. Truxton, August 1795.

THIS stream is probably generated by the great accumulation of water on the eastern coast of America between the tropics, by the trade winds which constantly blow there. It is known that a large piece of water ten miles broad and generally only three feet deep, has by a strong wind had its waters driven to one side and sustained so as to become six feet deep, while the windward side was laid dry. This may give some idea of the quantity heaped up on the American coast, and the reason of its running down in a strong

Strong current through the islands into the bay of Mexico, and from thence issuing through the gulph of Florida, and proceeding along the coast to the banks of Newfoundland, where it turns off towards and runs down through the Western islands. Having since crossed this stream several times in passing between America and Europe, I have been attentive to sundry circumstances relating to it, by which to know when one is in it; and besides the gulph weed with which it is interspersed, I find that it is always warmer than the sea on each side of it, and that it does not sparkle in the night: I annex hereto the observations made with the thermometer in two voyages, and possibly may add a third.* It will appear from them, that the thermometer may be an useful instrument to a navigator, since currents coming from the northward into southern seas, will probably be found colder than the water of those seas, as the currents from southern seas into northern are found warmer. And it is not to be wondered that so vast a body of deep warm water, several leagues wide, coming from between the tropics and issuing out of the gulph into the northern seas, should retain its warmth longer than the twenty or thirty days required to its passing the banks of Newfoundland. The quantity is too great, and it is too deep to be suddenly cooled by passing under a cooler air. The air immediately
over

* This is the Journal of the voyage hereto subjoined.



over it, however may receive so much warmth from it as to be rarified and rise, being rendered lighter than the air on each side of the stream; hence those airs must flow in to supply the place of the rising warm air, and meeting with each other, form those tornados and water-spouts frequently met with, and seen near and over the stream; and as the vapour from a cup of tea in a warm room, and the breath of an animal in the same room, are hardly visible, but become sensible immediately when out in the cold air, so the vapour from the gulph stream, in warm latitudes is scarcely visible, but when it comes into the cool air from Newfoundland, it is condensed into the fogs, for which those parts are so remarkable.

The power of wind to raise water above its common level in the sea, is known to us in America, by the high tides occasioned in all our sea-ports when a strong northeaster blows against the gulph stream.

The conclusion from these remarks is, that a vessel from Europe to North-America may shorten her passage by avoiding to stem the stream, in which the thermometer will be very useful; and a vessel from America to Europe may do the same by the same means of keeping in it. It may have often happened accidentally, that voyages have been shortened by these circumstances. It is well to have the command of them.

MARITIME

Observations of the warmth of the sea-water, &c. by Farenheit's thermometer, in crossing the Gulph Stream; with other remarks made on board the Pennsylvania Packet, Capt. Osborn, bound from London to Philadelphia, in April and May, 1775.

Date.	Hour.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Latitude N.	Longitude W.	Remarks.
April 10			62						
11			61						
12			64						
13			65						
14			65						
26			70						
27		60	70	SSE	WbS		37	38	Much gulph weed: saw a whale.
28	8 A.M.	60	70	SW	WNW		37	29	Colour of water changed.
	6 P.M.	70	64				37	35	No gulph weed.
29	8 A.M.	63	60	NNE	W	34	37	66	Sounded, no bottom.
	6 P.M.	65	71	NNE	WbS	44			Much light in the water last night.
	5 P.M.	66	72	NWbN	WbS	57			Water again of the usual deep
	11 dit.	66	66	NE	WbN	69			sea colour, little or no light in
30	8 A.M.	64	70	NE	WbN	24	37	20	it at night.
	12	62	70	ESE	WbN	43		63	Frequent gulph weed, water con-
	6 P.M.	64	72	S	WbN	25		53	tinues of sea colour, little light.
	10 dit.	65	65			60			Much light.
	7 A.M.	68	63	SSE	WNW	44	38	13	Much light all last night.
May 1	12	65	56	SW	WbN	31		72	Colour of water changed.
	4 P.M.	64	56	SW	WNW	18		23	
	10 dit.	64	57			31			
2	8 A.M.	62	53	WSW	NW	15	38	43	Much light. Thunder-gust.
	12	60	53	NW	WSW	10		74	
	6 P.M.	64	55	NW	WbN	10		3	
	10 dit.	65	55	NbW		30	38	30	
3	7 A.M.	62	54					75	

Observations

OBSERVATIONS.

5

Observations of the warmth of the sea-water, &c. by Fahrenheit's Thermometer; with other remarks made on board the Reprisal, Captain Wycks, bound from Philadelphia to France, in October and November, 1776.

Date.	Hour A. M.	Hour P. M.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Lat. N	Long. W	Remarks.
Octo. 31	10	4	76	70	SSE	E b S	135	38 12	70 30	Left the capes Thursday night, October 29, 1776.
Nov. 1	10	4	71	71	WSW	E 1/2 N	109	No ob.	68 12	
2	8		71	75	N		141	ditto.	65 23	
3	8	4	67	76	NW	ESE 1/2 E Eb S	160	37 0	62 7	Some sparks in the water, these two last nights.
4	9	4	68	76		N b E	194	36 26	58 8	Ditto.
5	8	8	68	76		NE	163	35 21	55 3	Ditto.
6	8	8	75	75	E b N	S 50 E	75	35 33	53 52	
7	8		77	78	SE b E	N 30 W	108	34 6	52 46	
8	9	4	75	77	S b E	N 49 E	175	38 2	50 1	
9	9	4	75	77	SW	N 33 E	175	39 39	46 55	

(CARRIED OVER.)

Observations of the warmth of the sea-water, &c. by Fahrenheit's Thermometer; with other remarks made on board the Reprisal, Captain Wycks, bound from Philadelphia to France, in October and November, 1776.

(CONTINUED FROM THE PRECEDING PAGE.)

Date.	Hour A. M.	Hour P. M.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Latit. N.	Long. W.	Remarks.
Nov. 9	8	4	70	71	E	N 17 E	64	40 39	46 27	
10	12			64						
11	8			63	SE	N 8 E	41	41 19	46 49	
12	12		56	61						
13	8	4		59	NNW	N 80 E	120	41 39	43 42	
14	all day			68	E	S 82 E	69	41 29	42 10	
15	8	Noon	70	72	ESE	N 74 E	111	42 0	39 57	
16		4	61	71	WSW	N 70 E	186	43 3	35 51	
17	8	Noon	65	68	SW	N 67 W	48	43 22	34 50	
18	all day	4		67	ESE	N 19 E	56	44 15	34 25	Some gulph weed.
19	8	Noon	65	63	SbW	N 75 E	210	45 6	29 43	
20				65	SW	N 80 E	238	45 46	24 2	
21	9	4		64	N	S 80 E	155	45 19	20 30	
22	10		60	62	S	N 88 E	94	45 22	18 17	
23	Noon			62	SSW	S 89 E	133	45 19	15 19	
24	do.			61	WSW	S 86 E	194	45 6	10 35	
25	do.			60	NNE	N 78 E	191	45 46	6 10	
26	do.		56	60	E	S 76 E	125	45 4	3 23	
27	do.			60		N 73 E	31	45 13	2 20	Soundings off Bellisle.
28		do.	54	58						

OBSERVATIONS.

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1785. A Journal of a Voyage from the Channel between France and England, towards America..

Dates.	Latit. N.	Long. W.	Therm. A.M.		Therm. P. M.		Winds.	Course.	Dist. Miles.	Variation of the Needle.	Therm. Noon.	
			Air.	Water.	Air.	Water.					A.	W.
July 29			62	57	63	58			60	West. 22° 0		
30			62	58	62	62			174			78
31			60	58	62	64			160			79
Aug. 1	49 15	4 15	63	62	60	64	East E	S W $\frac{1}{2}$ W		20 0		81
2	48 28	8 58	64	64	64	omitted.	ES	W S $\frac{1}{2}$ S		16 30		79
3	47 0	12 13	60	66	do.	66	NE	S W $\frac{1}{2}$ W	190	20 0		80
4	45 0	15 43	66	66	do.	68	NE	S W $\frac{1}{2}$ S	131	21 11		78
5	43 5	17 25	67	68	65	69	NE	S W $\frac{1}{2}$ S	166	21 11		79
6	41 3	19 44	70	70	71	70	NE	S W $\frac{1}{2}$ W	165			80
7	38 45	21 34	73	71	73	72	NE	S S W $\frac{1}{2}$ W	149			79
8	36 42	23 10	73	73	73	74	NE	S S W $\frac{1}{2}$ W	137			77
9	35 40	25 40	71	73	73	75	NW	W S W $\frac{1}{2}$ S	76			79
10	35 0	28 0	74	74	76	77	North	W S $\frac{1}{2}$ W	112			77
11	33 51	28 42	76	74	76	76	North	W $\frac{1}{2}$ S	143			78
12	33 30	31 30	76	75	76	76	NE	W $\frac{1}{2}$ S	103			79
13	33 17	33 32	76	76	78	77	SE	W $\frac{1}{2}$ N	50			80
14	33 22	34 31	76	76	81	79	WNW	S W $\frac{1}{2}$ N	35			78
15	33 45	35 0	78	79	79	78	WNW	S W $\frac{1}{2}$ N	38			79
16	33 14	35 30	80	78	81	80	West W	NNW	75			79
17	34 37	36 4	79	78	80	79	WNW	NNW	65			77
18	36 7	37 16	78	78	omitted.	78	NW	NNW	49			
19	36 38	38 0	77	77	78	77	WSW	NNW				

1785.

(CARRIED OVER.)

(CONTINUED FROM THE PRECEDING PAGE.)

MARITIME

N B. Longitude is reckoned from London, and the Thermometer is according to Fahrenheit.									
Dates.	Latit. N.	Long. W.	Therm. A.M.		Therm. P.M.		Winds.	Course.	Dist.
			Air.	Water.	Air.	Water.			
Aug 20	37 38	38 6	78	76	omitted.		West	N $\frac{1}{2}$ W	62
21	36 15	38 26	73	74	76		W N W	S b W	82
22	35 40	38 44	77	76	77		W b S	S S W	38
23	35 35	40 52	79	77	78		North W	W $\frac{1}{2}$ S	100
24	35 12	41 31	75	73	75		W N W	S W b W	omitted.
25	35 40	42 33	79	76	74		W b N	W N W $\frac{1}{2}$ N	74
26	35 30	42 44	79	76	76		S W b W	S W $\frac{1}{2}$ S	76
27	35 14	43 23	79	77	79		West	W S W $\frac{1}{2}$ S	80
28	34 23	44 0	78	76	78		N N E	S W b S	81
29	34 12	45 52	77	78	78		N N E	W $\frac{1}{2}$ S	78
30	34 5	48 31	78	78	78		East	W $\frac{1}{2}$ S	79
31	34 20	51 4	80	79	81		East	W $\frac{1}{2}$ N	80
Sept. 1	34 20	52 47	81	80	omitted.		S S W	W b N $\frac{1}{2}$ W	83
2	34 55	55 12	81	80	83		S W b S	W b N $\frac{1}{2}$ N	83
3	35 30	57 24	83	80	83		S W $\frac{1}{2}$ W	W b N $\frac{1}{2}$ N	84
4	35 50	59 1	82	80	83		S S W	W b N $\frac{1}{2}$ N	81
5	35 55	61 0	81	81	82		S S W	W $\frac{1}{2}$ N	81
6	36 20	62 30	80	80	79		N W b N	W b N	82
7	34 50	63 10	87	81	78		N W b W	S S W	78
8	34 45	64 40	75	79	75		North	W $\frac{1}{2}$ S	78
9	35 43	66 42	75	79	77		N E	W N W	75
10	37 20	68 40	77	73	77		E N E	N W	78

OBSERVATIONS.

OBSERVATIONS.

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OBSERVATIONS.

July 31. At one P. M. the Start bore WNW distant six leagues.

August 1. The water appears luminous in the ship's wake.

—2. The temperature of the water is taken at eight in the morning and at eight in the evening.

—6. The water appears less luminous.

—7. Formegas SW distant $32\frac{1}{2}$ deg. St. Mary's SW $\frac{1}{2}$ S 33 leagues.

—8. From this date the temperature of the water is taken at eight in the morning and at six in the evening.

—10. Moon light, which prevents the luminous appearance of the water.

—11. A strong southerly current.

—12. Ditto. From this date the temperature of the air and water was taken at noon, as well as morning and evening.

—16. Northerly current.

—19. First saw gulph weed.

—21. Southerly current.

—22. Again saw gulph weed.

—24. The water appeared luminous in a small degree before the moon rose.

—29. No moon, yet very little light in the water.

—30. Much gulph weed to-day.

—31. Ditto.

Sept. 1. Ditto.

—2. A little more light in the water.

—4. No gulph weed to-day. More light in the water.

—5. Some gulph weed again.

—6. A little light in the water. A very hard thunder-gust in the night.

—7. A little gulph weed.

—8. More light in the water. Little gulph weed.

—9. Little gulph weed. Little light in the water last evening.

—10. Saw some beds of rock-weed; and we were surprized to observe the water six degrees colder by the thermometer than the preceding noon.

This day (10th) the thermometer still kept descending, and at five in the morning of the 11th. it was in water as low as 70, when we struck soundings.

soundings. The same evening the pilot came on board, and we found our ship about five degrees of longitude a-head of the reckoning, which our Captain accounted for by supposing our course to have been near the edge of the gulph stream, and thus an eddy-current always in our favor. By the distance we ran from Sept. 9, in the evening, till we struck soundings, we must have then been at the western edge of the gulph stream, and the change in the temperature of the water was probably owing to our suddenly passing from that current, into the waters of our own climate.

On the 14th of August the following experiment was made. The weather being perfectly calm, an empty bottle, corked very tight, was sent down 20 fathoms, and it was drawn up still empty. It was then sent down again 35 fathoms, when the weight of the water having forced in the cork, it was drawn up full; the water it contained was immediately tried by the thermometer, and found to be 70, which was six degrees colder than at the surface: The lead and bottle were visible, but not very distinctly so, at the depth of 12 fathoms, but when only 7 fathoms deep, they were perfectly seen from the ship. This experiment was thus repeated Sept. 11, when we were in soundings of 18 fathoms. A keg was previously prepared with a valve at each end, one opening inward, the other outward; this was sent to the bottom in expectation that by the being both open when going down, and both shut when coming up, it would keep within it the water received at bottom. The upper valve performed its office well, but the under one did not shut quite close, so that much of the water was lost in hauling it up the ship's side. As the water in the keg's passage upwards could not enter at the top, it was concluded that what water remained in it was of that near the ground, and on trying this by the thermometer, it was found to be at 58, which was 12 degrees colder than at the surface.

This last Journal was obligingly kept for me by Mr. J. Williams, my fellow passenger in the London Packet, who made all the experiments with great exactness.



MEMOIR OF JONATHAN WILLIAMS,

On the use of the Thermometer, in discovering Banks, Soundings, &c.

Read Nov.

19, 1790.

I HAVE hitherto delayed making a public communication of my sea journals, from an apprehension of being thought too forward in calling the attention of the Philosophical Society to the subject of them; but being impressed with a belief, that by noticing the changes in the heat of the sea water, a navigator might always know when he is in soundings, and thereby be able to escape the dangers arising from unexpected currents, and erroneous reckoning, I cannot think myself justifiable in longer hesitating to submit my remarks to their learned and judicious examination.

This sense of duty is strengthened by the recollection of many melancholy instances where mariners, in full confidence of being at a distance from land, have, with crouded sails, rushed on to destruction; and I was once within half an hour's time of being shipwrecked on the rocks of Scilly, when the return of day presented to our view the frightful rocks we had so narrowly escaped.

If it should be found that the use of the thermometer would be an improvement in the art of navigation, I shall be abundantly rewarded by the reflection of having contributed to the service of humanity, which is the common cause of all men. If it should, on the contrary,
appear

appear that I am mistaken, either in the facts or the conclusions deduced, I trust that the desire of doing good, the only motive that actuates me, will meet with indulgence from every candid mind.

In the months of August and September, 1785. I was a fellow passenger with the late Doctor Franklin from Europe to America, and made, under his direction, the experiments mentioned in his description of the course of the gulph stream, an account of which was annexed to his maritime observations, and published in the Philosophical Transactions Vol. II. page 328, I then determined to repeat these experiments in my future voyages. Accordingly on a passage from Boston to Virginia in October 1789, I kept a journal of the heat of the air and water at sun rise, noon and sun set; I then noticed that the sea-water out of soundings was about ten degrees warmer than that on the coast, and it very naturally occurred to me that the thermometer might become an useful nautical instrument to indicate an approach to the shore. I thought it prudent, however, to keep this idea to myself till after I had made a course of fair and repeated experiments, which I accordingly did during four passages, 1st, the one from Boston to Virginia abovementioned, 2d, from Virginia to England, 3d, from England to Halifax, and 4th, from Halifax to New-York. By consulting these journals and the observations made at the dates written, together
with

with the tracks of the ship's way marked on the chart annexed, it will not only appear that Doctor Franklin's account of the warmth of the gulph stream has been amply confirmed, but also that banks, coasts, islands of ice, and rocks under water, may be discovered when not visible, and when the weather is too boisterous to find, with no other trouble than dipping the thermometer into the sea water. It is well known to sailors, that the water on the banks of Newfoundland is cold, but as they only try this, with the hand, their remarks are contradictory owing to the varied temperature of the hand, and I never heard of any further application of what they think merely a matter of curiosity. Doctor Franklin's observations had the knowledge of currents for their object, and this extension of his discovery did not occur; but as I am indebted to his instructive conversation and example, for my inducement to pursue philosophical researches when in my power to do so, he may be considered as the original cause of what is now presented for examination.

It will be proper to suspend any conclusions till the journals have been attentively considered, but as a guide to the object of them, it may not be amiss to state such facts as it is presumed the experiments have a tendency to establish.

1. The water over banks is much colder than the water of the main ocean, and it is more cold in proportion as it is less deep.

2. The water over small banks is less cold than that over large ones.

3. The water over banks that are near the coast is warmer than that over banks far distant, but it is colder than the adjacent sea.

4. The water over banks of the coast, *i. e.* those immediately connected with the land above water, is warmer than that over those which admit deep water between them and the coast; but still it is colder than the adjacent sea.

5. The water within capes and rivers does not follow the above rules; it being less agitated, and more exposed to the heat of the sun, and to receive the heat from the circumjacent land, must be colder or warmer than that in soundings without, according to the seasons, and temperature of the atmosphere.

6. The passage, therefore, from deep to shoal water may be discovered by a regular use of the thermometer, before a navigator can see the land; but as the temperature is relative, no particular degree can be ascertained as a rule and the judgment can only be guided by the difference. Thus in August I found the water off Cape

Cod

Cod to be 58° . by Fahrenheit, and at sea it was 69° ; in October the water off Cape Cod was 48° . and at sea it was 59° . This difference was equally a guide in both cases, though the heat was different at different seasons.

I do not presume to say what is the cause of this difference of heat between the sea and bank water, but if a navigator were to observe it when near an island of ice, he would very naturally say that the ice conducted the heat from the circumjacent water, and left it colder than that at a distance. And as it is well known that stones and sand are great conductors of heat, it seems probable that banks also conduct the heat from the adjacent water, though not so rapidly as ice. The heat of the water may indeed be supposed to seek its equilibrium, but as long as islands of ice and banks continue to conduct, there must be some difference, and this it is, which, by attention, may be made a faithful sentinel to give an alarm when danger is near.

I have thought it my duty to present my journals as they were written at sea, to avoid the suspicion of having added any thing from the suggestions of the imagination. While this will be received as a circumstance favourable to the truth of them, I hope it will also operate as an apology for their imperfections.

The journal A. from Boston to Virginia, shews that the water on the coast of Massachusetts, was at 48° ; at sea between that coast and the stream, 59° ; in the gulph stream at its edge, 67° ; between that and the coast of Virginia farther southward, 64° ; and in soundings on that coast, 56° . At that season (in October, just after the warm weather) the water grew warmer as we approached the land.

The journal B. from Virginia to England, shews that in December, the water in the coast of Virginia was at 47° ; between the coast and the stream, 60° ; and in the stream, 70° . This current being in our favour, we did not avoid it, and the water continued with little variation, till we came near the banks of Newfoundland, when the thermometer fell from 66 to 54; passing these, it rose again to 60° . and then continued a very gradual descent as we went to the northward, till we struck soundings, when it was at 48° .

It may be here observed, that the decrease in the heat of the water was so gradual as to give but one degree in a day's run, while in going to, or coming from the coast of America, the thermometer will alter 8 or 10 degrees in a few hours run. It is well known, by sounding, that the English coast extends with a very gradual descent to a great distance. It is also known that the American coast does not extend very far, and the water is suddenly deep. Let these facts be compared with the changes

changes in the thermometer, on the two coasts, and they will agree with each other and confirm what has been said about the usefulness of that instrument.

It may be observed in Doctor Franklin's journal on board of the *Reprisal*, that in November 1776, when near the banks of Newfoundland, his thermometer fell ten degrees, though considerably to the Southward of them, and after passing them, it rose nearly to its former state: the Doctor did not make any observation on this circumstance; but it agrees with my journal, in nearly the same place, made nine years afterwards.

The journal C. from England to Halifax, shews the changes in the heat of the water as we sailed over banks and deep water alternately, with an accuracy that I confess, exceeded my expectation, the land appearing as the thermometer indicated our approach to it.

The journal D. from Halifax to New-York not only shews the variety of depths we passed over, but indicates the inner edge of the gulph stream. As by the thermometer and soundings it appeared to me that the ship was a-head of the reckoning, I made allowances for the eddy current of that stream in our favour, and comparing these with the chart, I noted in the journal, the longitude I thought we were in, under that calculated by the ship's officers: what encouraged this opinion,

was the disagreement between the soundings by the lead, and those marked on the chart in the places where, by the common reckoning, the ship was supposed to be; while upon the other supposition they both agreed. When we made the land this latter reckoning turned out accurate, and I won a small bet of the Captain who candidly acknowledged the usefulness of the thermometer, and declared that he would in future, always have one on board.

Finding the coast of America to grow suddenly deep as it approaches the gulph stream, and finding continued soundings from Cape Sable to New-York, I am induced to believe that it has its shape according to the course of that current, and that it is connected in a sweep from the banks of Newfoundland to Florida, the various banks between being only eminences of the coast. If my apprehension of the accuracy of thermometrical observation is well founded, it would be an easy thing to make a general survey of the coast under water, more particularly than has hitherto been, or could be done by sounding.

On the chart annexed, the tracks of my several passages are marked with the daily heat of the water in degrees according to Fahrenheit, by which the variations on the approach to land may be seen at one view. The edge of the gulph stream is also traced according to the experiments

experiments as far as the banks of Newfoundland: how far it runs to the eastward I do not pretend to say, but having found a current in the natural direction of its sweep among the western islands, I am inclined to think it extends so far, before it turns off to the southward. It may be observed, however, that as this stream, like all other currents, must be affected by tempests on either side; it may, as these prevail, run somewhat nearer or somewhat farther distant from the coast.

In confirmation of what has been said about the eddy current of the gulph stream, I have extracted from the journal of an officer belonging to the British ship of war *Liverpool*, some observations which describe this eddy on both sides of the stream,* two other extracts from the same journal† describe a current among the western Isles, which is perhaps the gulph stream, then turning to the southward. This journal was communicated to me by Capt. Schuyler of the British packet, on board of which I made my last experiments and observations.

‡ In addition to my journals, I have subjoined an account of some experiments on fish, which show that their animal heat was 16 degrees colder than the water at the surface; from which it may be supposed that the water at bottom is in proportion colder than that above. It
may

* Appendix No. I.

† Appendix No. II. and III.

‡ Appendix No. IV.

may be naturally suggested, that trying the heat of the water at the surface, (the only way in one's power when sailing rapidly through it,) is too inaccurate to be depended on since the surface must be heated by the atmosphere. To this it may not be amiss to answer.—1. That by repeated experiments at the depth of 30, 40, and 60 fathoms, I have found the water below, out of soundings, to be no more than six degrees colder than that above; and at four or five fathoms deep, when the sea was agitated, there was no difference worthy notice. 2. When the sea is not agitated and the surface, by being exposed to a hot sun, is warmer, the weather being calm, it is easy to have water from a considerable depth; this I have found to make a difference of one or two degrees only, and it is easy to make the allowance. 3. The difference of heat which marks an approach to land is sufficiently sensible at the surface for the purpose of giving notice of danger. I have generally found it to be 6° in three hours run, and long before we were near enough to be in danger. Upon the whole, as it is fact, and not argument which should inspire belief, I wish every doubting navigator to endeavour to confute me by making other experiments, and thereby, if he can, detect the fallacy of mine.

JONATHAN WILLIAMS.

OBSERVATIONS.

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These Journals, as they were presented to the society, contained the experiments in detail; but it was thought expedient in the publication of them, to suppress all those, which, by having nearly similar results, may be considered as repetitions of the preceding, or gradual approaches towards the succeeding ones. The reader may depend, however, that nothing is altered, and that the heat of the water was taken at least three times every day during all the voyages, and when passing over banks, or approaching the coast, almost every hour, as well by night as by day. N. B. The Thermometer used was on Fahrenheit's scale.

A. A Thermometrical Journal of the temperature of the atmosphere and the sea, on a passage from Boston towards Virginia, on board of the schooner America, Capt. Brace.
By JONATHAN WILLIAMS.

Dates.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
1789.					
Oct. 11	Sun set.	42° 5'	69° 40'	58	48
12	Sun rise.			50	54
	Noon.	40 23	68 46	50	52
	Sun set.			52	59
13	Sun rise.			57	65
	Noon.	38 40	70 35	60	67
	Sun set.			64	66
14	Sun rise.			65	62
	Noon.	38 46	71 58	69	61
	Sun set.			66	64
15	Sun rise.			70	65
	Noon.	38 25	73 10	67	64
	Sun set.				
16	Sun rise.			59	63
	Noon.	37 45	73 40	60	64
	Sun set.			61	64
17	Sun rise.			62	64
	Noon.	37 36	74 1	66	64
	Sun set.			65	64
18	Sun rise.			60	57
	Noon.	37 34	74 45	60	56
	Sun set.			50	57
19	Sun rise.			56	60
	Noon.	37 4	76 4	58	58

NOTES.

October 11—sun set. Sailed at 8 A. M. from Boston; and at sun set, we were off Cape Cod, which is in lat. 42. 5. N and long. 69. 40. W from London. See John Hamilton Moore's practical navigator.

October 12—noon. No symptom of the gulph stream in this longitude.

—sun set. We now probably approach the gulph stream, the water being 7° . warmer than at noon.

October 13—sun rise. At midnight, we had made nearly SW course distant 80 miles; the water then was at 60.

October 13—noon. We are now probably within the stream, the water being 15° . warmer than yesterday at this time.

October 13—sun set. We had a good observation at noon; we are probably still in the stream, the water continuing warm.

October 14—sun rise. We have made about a west course during the night, distant about 52 miles.

October 14—noon. It appears by observation, that we are 18 miles north of our reckoning; hitherto our reckoning has appeared accurate.

October 14—sun set. The water yesterday noon was 6° . warmer than at the same time to-day, yet the air was 9° . warmer to-day than at the same time yesterday. By this difference of temperature, and by the loss of 18 miles distance, it is probable that we were within the stream yesterday, and carried to the northward by its current; thus it appears, that in the lat. $38^{\circ}. 43'$. N, the western edge of the stream extends as far as long. $71. 15$. W, which is the mean between yesterday and to-day's reckoning.

October 16—noon. I sent a well corked bottle 30 fathoms deep, and drew it up empty; I sent it again 60 fathoms deep, and drew it up full, this water was then taken at a depth somewhere between 30 and 60 fathoms, and it was by the thermometer at 58° . six degrees colder than at the surface, 64° .

October 17—noon. Observe how regular the temperature of the water has been during four days, *i. e.* since leaving the stream.

October 18—sun rise. By the sudden change in the heat of the water, I suspect we are drawing near soundings.

October 18—noon. Sounded, but no bottom, with 60 fathoms of line. No observation for the first time since we have been out.

October 18 At 8 P. M. got bottom 23 fathoms, heat of water 56° . At midnight 21 fathoms.

October

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October 17. At 2 A. M. 18 fathoms, at 4 A. M. 14 fathoms, at 8 A. M. made Cape Charles, WNW, at 9 Cape Henry, W by SW off Willoughby's point, in the mouth of James river. Cape Charles, by John Hamilton Moore's practical navigator, is in lat. $37^{\circ} 9'$ N long. $75^{\circ} 50'$ W. We are now about 16 miles within the Cape, thus the reckoning proves to be very accurate.

N. B. The water appears somewhat warmer in shoal than in deep soundings, within the Cape.

B. A Thermometrical Journal of the temperature of the atmosphere and the sea, on a passage from Virginia to England, on board of the brig Mercury, Captain Thompson.

By JONATHAN WILLIAMS.

Dates.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
1789.					
Nov. 30	Noon.	$37^{\circ} 0'$	$75^{\circ} 43'$	42°	47°
	Sun set.			42	50
Dec. 1	Sun rise.			42	54
	Noon.	$36 30$	$70 12$	44	60
	10 P. M.			50	70
2	Sun set.	$36 30$	$68 47$	58	67
3	Noon.	$36 30$	$65 39$	60	70
	Sun set.			63	71
4	Sun rise.			59	69
	Noon.	$37 3$	$62 13$	60	68
	Sun set.			59	67
5	8 A. M.			56	66
7	Sun set.	$38 7$	$54 4$	66	68
8	Noon.	$38 43$	$52 12$	68	66
9	Sun rise.	$39 56$	$48 52$	66	62
10	Sun rise.			46	54
	Noon.	$40 10$	$46 12$	54	60
	Sun set.			52	62
11	Noon.	$40 44$	$43 39$	56	60
13	Noon.	$42 22$	$39 35$	62	59
14	Sun rise.	$43 54$	$36 4$	61	58
15	Sun rise.			58	57
	Noon.	$44 58$	$32 27$	60	55
16	Noon.	$45 58$	$29 0$	56	53
22	Sun rise.	$48 22$	$21 2$	48	50
24	Midnight.	$49 48$	$13 54$	46	49
25	Noon.	$49 40$	$10 14$	48	48
27	Noon.	$49 56$	$3 32$	58	49
28	Noon.	$50 24$	$2 22$	50	49

NOTES.

NOTES.

Nov. 30. Sailed this morning from Hampton Road; at noon Cape Henry bore West, distant 2 leagues.

Dec. 1. Entered the Gulph stream, at 10 P. M.

December 10.—sun rife. I suppose this coldness to be owing to the banks of Newfoundland, which are in this Longitude.

December 22. Since the 16th there has been little or no alteration 'til to-day.

December 25. At 8 P. M. sounded in 75 fathoms.

December 27. At noon sounded in 40 fathoms.

December 28. At noon saw Portland.

C. A Thermometrical Journal of the temperature of the atmosphere and the sea, on a passage from Falmouth in England, to Halifax in Nova Scotia, on board the British packet *Chesterfield*, Cap. Schuyler.

By JONATHAN WILLIAMS.

Dates. 1790.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
June 12	Noon.	49° 57'	5° 14'	61°	55°
	6 P. M.			57	57
14	Noon.	48 11	12 18	61	58
15	8 P. M.	47 25	16 16	60	59
21	Noon.	48 7	25 16	62	57
22	8 A. M.	47 19	26 11	59	58
23	Noon.	46 38	27 55	62	60
24	6 P. M.	45 13	28 29	64	62
25	Noon.	44 46	30 32	67	63
26	7 P. M.	44 53	32 15	66	62
27	Noon.	44 51	33 29	63	61
30	Noon.	44 56	36 21	64	60
July 1	Noon.	44 0	37 2	66	64
2	8 P. M.	44 31	38 25	65	61
3	8 P. M.	44 52	39 56	62	60
4	Noon.	44 23	40 53	66	62
5	6 P. M.	44 20	43 25	66	63
6	6 A. M.			66	62
	Noon.	44 43	46 7	62	57
	1 P. M.			62	55
	4 P. M.			58	53
	5 P. M.			55	51
	6 P. M.			60	56
	7 P. M.			59	57
	Midnight.			59	55

(CARRIED FORWARD.) C.

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C. A Thermometrical Journal of the temperature of the atmosphere and sea, on a passage from Falmouth in England, to Halifax in Nova Scotia, on board the British packet *Chesterfield*, Cap. Schuyler.

By JONATHAN WILLIAMS.

(Continued.)

Dates. 1790.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
July 7	4 A. M.			58°	54°
	6 A. M.			56	50
	7 A. M.			56	49
	10 A. M.			56	51
	11 A. M.			55	53
	Noon.	45° 0'	47° 57'	55	51
	6 P. M.			55	49
8	6 P. M.	45 14	49 13	53	47
9	8 A. M.	45 10	51 9	53	47
10	8 A. M.	44 54	53 39	57	51
11	8 A. M.	44 52	54 57	58	53
	6 P. M.			60	54
12	8 P. M.	44 49	56 16	55	55
13	8 A. M.	44 30	58 28	55	53
	8 P. M.			56	54
	10 P. M.			56	53
14	8 A. M.			60	56
	Noon.	44 33	59 54	60	61
	Midnight.			57	57
15	2 P. M.	44 50	61 20	60	57
	5 P. M.			60	53
	8 P. M.			60	56
16	Noon.	44 34	62 17	61	57
	8 P. M.			60	53
17	6 A. M.			59	52
	Noon.			62	57
18	4 A. M.	At the mouth of Halifax H.		54	52

NOTES.

July 1. In the evening, I strained a bucket of water through a towel, and the luminous appearances so common in the sea, remained on the cloth.

July 6—at 5 P. M. I suppose we are on Jacquet's Bank.—7 P. M. I suppose we are between Jacquet's and the Grand bank of Newfoundland.

July 7—at 4 A. M. These irregular degrees of heat indicate eminences in the valley between Jacquet's and the Grand Bank.

July 9—at 8 A. M. Sounded in 40 fathoms.

July 10—at 8 A. M. Sounded in 45 fathoms.

July 11—at 8 A. M. Sounded 56 fathoms.—6 P. M. Sounded 75 fathoms.

July

July 12—at 8 P. M. Sounded, no bottom, in 110 fathoms, over the Grand Bank.

July 13—at 8 A. M. Sounded in 42 fathoms; perhaps on the whale Bank.—8 P. M. Sounded 40 fathoms.—10 P. M. Sounded 35 fathoms.

July 14—at 8 A. M. Sounded in 38 fathoms.—Noon. Sounded 60 fathoms, calm, and bright sun.

July 15—at 2 P. M. Saw land.—5 P. M. Tacked and stood off land, sounded 13 fathoms.—8 P. M. Land out of sight.

July 16—noon. Standing in for land.—8 P. M. Tacked and off the land.

July 17—6 A. M. On Jeddore Bank.—Noon. Off the Bank.

Observations on a passage from Falmouth to Halifax.

By JONATHAN WILLIAMS.

1790. June 17. The very gradual increase in the heat of the water as we leave England indicates a small descent of the coast, which as far as soundings go, is known to be the case.

July 6. Here we find a sudden change of 7 degrees in the heat of
lat. 44. 43. N the water, which indicates our approach to the banks of
lon. 46. 7. W Newfoundland, though not in such soundings as we could obtain.

We tried with 160 fathoms but the lead was only about 12 pounds, and the line was a very thick one: perhaps the line floated the lead. At 5 P. M. the water was still colder 4 degrees; but at 8 A. M. it grew warmer again 6 degrees, this seems to indicate a passage over a bank, into water, as deep as when we discovered the first change.

July 7. We are now in cold water again (49) 13 degrees colder
lat. 45. 0. N than the ocean water had regularly been during 12 days
lon. 47. 57. W previous to the first change, except only the small variations of a more northern or more southern course, these changes seem to indicate our entrance on another bank. There is a bank laid down in the charts, by some called Jacquet's bank, but by the older charts called False bank, over which we have probably passed. In this longitude, but
farther

farther south, both by Dr. Franklin's and my own observations, the water grew suddenly cool. This seems to confirm the supposition of this outer bank, the southernmost point of which I suppose to extend as far as lat. 40. 0. N. We hove too in order to try the soundings, but the force of the back sail carried away the main top mast head, and brought the top gallant sail, mast and rigging down, this confusion interrupted the sounding; and we had only 80 fathom of line out, when it was hauled in.

July 8. At 6 P. M. the water was only 2 degrees colder (47°) than when we were interrupted in sounding, and we got bottom in 40 fathoms.

July 12. From the last sound to this time the thermometer has lat. 44. 49. N varied, regularly as the soundings varied the water being lon. 56. 16. W warmer when deeper, and cooler when shoaler. It is now at 55, which is 8 degrees warmer than when we had 40 fathoms. We now sounded and could not reach bottom with 110 fathoms of line. This indicates that we are off the Grand bank, and within it. By taking our distance from the time the thermometer first fell to 54, to the last time it stood at that degree, we may give an account of the width of the soundings on this Grand bank, though it probably extends much farther, but in deeper water. This is noted on the chart. The variations in the thermometer between last night and this morning, indicate our passage over an eminence of the bank, called the Whale bank, situated on its inner edge.

July 13. Thermometer at 8 A. M. was at 53, two degrees lat. 44. 30. N colder than when we could not reach bottom with 110 lon. 58. 28. W fathoms of line: and we sounded in 42 fathoms. This indicates our entrance on another bank, which is called in the charts Banquereau. It is observable that the water of small banks is not so cold as that of large banks, and this seems natural, if it is supposed that the conducting power of the land, taking away part of the heat of the water, is the cause of the changes in the thermometer;

for

for that power must have less effect, as the quantity of the ground under water is less: and this must be still more remarkable when the bank is immediately connected with land above water, for such land conducting heat away from the atmosphere, and receiving much from the sun, must require less from the water. This remark has been uniformly confirmed in all my experiments within Capes, where the water is much warmer than in soundings without them. And it is further observable, that the water on the coast of America on the edge of soundings, is not above 6 or 8 degrees colder than deep water; but on the banks of Newfoundland it is from 12 to 15 degrees colder.

July 14. Here we have the water 57° , which is 2° warmer than lat. 44. 33. N when we could not get bottom between the banks, yet lon. 59. 54. W we have 65 fathoms, at noon it was up to 61. and we had the same soundings; but as it was calm weather, and as we had a hot sun, allowance must be made for its influence, and therefore no certain conclusion can be drawn. The depth of the water however indicates our going off Banquereau, and the white sand of the bottom indicates that we are on the edge of the bank which is connected with the Isle of Sable. This also accounts, from the above mentioned principle, for the unexpected warmth of the water.

July 15. We saw the land at 2 P. M. and now we are in 13 fathoms of water, thermometer 53. This land agrees with the description of that about St. Mary's river, and tracing our course back, shews us to have been last night, and the preceding days, in the very places indicated by our reckoning, thermometer, and soundings. We tacked and stood off.

July 18. The thermometer, when we stood off the land, rose up to 57. and when we came on and made the high lands of Off Halifax Harbour, it indicated Jeddore banks by falling to 52. when being becalmed we caught fish; leaving the bank it rose to 57. and now we are in sight of our port it stands at 52.

OBSERVATIONS.

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D. A Thermometrical Journal of the temperature of the atmosphere at sea, on a passage from Halifax to New York, on board of the British packet *Chenier*, Captain Schuyler.

B. J. WILLIAMS.

Dates. 1790.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
July 21	9 A. M.	Halifax	Harbour.	56°	53°
	11 A. M.	Without the	Harbour.	55	52
	4 P. M.			64	56
22	6 A. M.			56	50
	Noon.	43° 12'	64° 0'	56	53
	4 P. M.			56	50
24	7 P. M.			56	54
	8 A. M.			56	50
	10 A. M.			58	53
25	Noon.	41° 57'	65° 1'	68	58
	6 P. M.			62	57
	Midnight.			62	56
26	Noon.	41° 53'	65° 33'	64	58
	4 P. M.			64	55
	6 P. M.			62	53
27	Midnight.			62	60
	3 A. M.			62	53
	6 A. M.			60	57
28	Noon.	41° 8'	66° 56'	64	60
	4 P. M.			64	62
	3 A. M.			60	54
29	7 A. M.			62	60
	Noon.	40° 44'	67° 32'	64	56
	4 P. M.		68° 30'	64	54
30	8 P. M.			65	59
	10 P. M.			64	55
	1 A. M.			64	56
31	6 A. M.			67	61
	Noon.	40° 44'	68° 6'	68	60
	8 P. M.		69° 40'	69	64
Aug. 1	10 P. M.			69	64
	4 A. M.			68	63
	Noon.	40° 25'	68° 20'	68	63
30	10 P. M.		70° 30'	65	64
	Noon.	40° 23'	69° 14'	67	66
	4 P. M.		71° 10'	69	67
31	8 P. M.			69	68
	Midnight.			70	69
	3 A. M.	40° 29'	70° 51'	70	68
Aug. 1	4 A. M.		72° 30'	70	68
	9 A. M.			66	66
	4 P. M.	40° 29'	73° 40'	68	66

* N. B. By the soundings and the thermometer, I suppose the true longitude to be as marked under the reckoning.

NOTES.

July 21. Sailed at 8 A. M.—4 P. M. Land out of sight.

July 22—6 A. M. I suppose we are on Roseway bank.—Noon. I suppose we are between Roseway and Brown's bank.—4 P. M. I suppose we are on Brown's bank.—7 P. M. I suppose we are off do.

July 24—6 P. M. Tried current and found it NE 1 knot, no bottom in 80 fathoms.

July 25—noon. Much Gulph weed, a whale, two sharks, and many porpoises.—6 P. M. Bottom in 42 fathoms, no Gulph weed.—Midnight. Bottom in 32 fathoms, flood north.

July 26—3 A. M. Bottom in 32 fathoms, flood southward.—4 P. M. Bottom in 50 fathoms, flood North.

July 27—3 A. M. Bottom 35 fathoms, flood southward.—7 A. M. Stood west.—4 P. M. Bottom in 28 fathoms.—8 P. M. Bottom in 40 fathoms.—10 P. M. Bottom in 30 fathoms.

July 28—1 A. M. Bottom 32 fathoms, flood SE.—6 A. M. Bottom in 43 fathoms, flood SW.—Noon. Bottom 36 fathoms, flood ESE.—8 P. M. Bottom in 65 fathoms, wore ship, almost calm.—10 P. M. No bottom, I suppose we are within the influence of the Gulph stream; in its eddy perhaps.

July 29—4 A. M. Bottom in 57 fathoms, flood west.—10 P. M. Bottom 45 fathoms, the water being warmer than in the same depth when I thought we were near the shoals, I am induced to believe that this bottom is that of the coast.

July 30—8 P. M. Bottom in 56 fathoms, mud.

July 31—3 A. M. Bottom in 63 fathoms, mud. The muddy bottom shews that we are within the shoals and banks of the coast.

August 1—9 A. M. Saw the land off Long Island, bearing north.—4 P. M. New York Light House in sight, bearing west. N. B. Since 2 A. M. we have been going from 5 to 7 knots, *i. e.* about 50 miles W which makes the longitude by thermometrical reckoning and soundings, 73. 40. W at noon, which turns out accurate, the land being in 74. 0. W.

Observations on a voyage from Halifax towards New-York.

1790. July 21. Sailed this morning from Halifax. The water at the harbour's mouth and just within Chebucta head, was at 53. but without it was at 52.—In land locked places I have generally found the water warmer than in even greater depths, on the borders of the ocean.

22. When we lost sight of land the water was at about 56. but at 6 this morning it having cooled to 50. I suppose we are passing over Roseway bank.

At noon the heat of water had risen to 53. which makes me suppose we are over the ground between Roseway and the other bank called in some charts Brown's bank, and at 4 the water cooling again to 50. I suppose we are on this last mentioned bank.

24. The water at noon yesterday growing as warm as 56. I suppose we are on the SE edge of Brown's bank. As we
 Lat. 41. 57. afterwards hauled up more to the westward, and as the
 Long. 65. 1. water at 8 this morning cooled to 50. again, I supposed we had returned more on the bank. But at noon the thermometer rose to 58. As it was calm, and the sun hot, I made some allowance for that cause, but supposed we had got off soundings, and as at 6. (the air being 69. cooler than at noon) it was at 57. I was confirmed in this.—It being still calm, and there appearing some Gulph weed, we hoisted out the boat to try the current which we found to set NE nearly 1 knot. This puzzled me, I could not conceive ourselves to be in the Gulph stream, because the water was not hot enough for that supposition, and as the iron pot by which we anchored the boat, was not at bottom though 80 fathoms of line were out, I thought the heat 57. fully accounted for by the depth of water; but about 7 when we had made a little way through the water, it became again calm, and we then saw and heard the ripple of a current as evidently as we could have expected over a shoal. I could not account for this any other-wise than by supposing it to be the Gulph stream, yet it appeared

appeared impossible that it should come so near the bank. Our Captain resolved to try again if there was a current here, at a distance from this ripple and in a calm. He accordingly hoisted out the boat again, and the current was found to set SE by S about $\frac{3}{4}$ knot. The evidence of this various current in so short a space, the heat of the water not being raised to the heat of the stream, and our situation to the northward made me conclude this to be the whirlpools of the eddy of the Gulph stream just on the northern edge of it.

July 25. Noon. The water still continuing till noon nearly at the same
 Lat. 41. 53. temperature, and our course being to the west southerly,
 Long. 65. 33. I concluded that our situation with respect to the stream

was nearly the same as last remarked, this was confirmed by the passage of immense quantities of Gulph weed, a deal of scum and mucus, with a whale, two or three sharks, and a school of porpoises in the course of the morning; but in the afternoon we fell off further to the northward, and at six P. M. the water was from 55. to 53. no Gulph weed to be seen, and in soundings of 42 fathoms. We tacked and stood south at 8 P. M. and I was astonished to find at midnight that the water was heated to 60. though the soundings were only 32 fathoms. Here again I could account for this only by the influence of the Gulph stream, which the Capt. seemed to think

26th. probable, and tacked to the northward, the wind being still at about west, and by 3 A. M. the thermometer fell to 53. with the same soundings, when we again tacked and stood to the southward. I then tried the heat of the water by the thermometer, regularly every hour, and by 5 P. M. it was up to 62. The soundings then were 46

27th. fathoms:—We tacked and stood north, and at midnight it was again down to 55. at 3 A. M. to 54. the sounding then about 35 fathoms; we then stood south when it returned to 60. Thus upon three successive tacks each way we cooled or warmed the water as we were standing either northward or southward from 6 to 9 degrees.—I could

only

July 27.

only account for this (the soundings varying but very little) by supposing that when we stood southward we got into the warm influence of the Gulph stream, and as we stood northward we got out of it. I do not think we got into the stream itself, because I should in that case have expected the water to have been much warmer, but probably we have been very near, perhaps upon the edge of it: and perhaps we have had a benefit instead of a disadvantage, by an eddy westerly current: that we have been near it, seems pretty clear, for when we warmed the water we saw plenty of Gulph weed, and the weather was clear, when we cooled the water we saw no Gulph weed and the weather was foggy.

Perhaps we may be farther to the westward than we think: time and a good look out will discover.

July 30.

Lat. 40. 25.

Long. 70. 30.

Since the last observation relative to the stream and soundings, I have kept the thermometer going almost every hour except when we were standing off the shore, and by examining the soundings according to those marked in Mr. Des Barres' chart, I have regularly traced them, and if we were to suppose that a current was setting us about one knot per hour to the westward, the soundings would agree very well. When in about lat. 40. 25. we were standing off shore, we warmed the water to 64 and got 45 fathoms, this heat I account for by the influence of the stream, it being greater than the proportion as to soundings, for in 40 fathoms farther toward the shore it was only 60. In looking over my journal from Boston to Virginia in Capt. Brace, I found that in nearly the same latitude the heat increased in about the same time from 52. to 59. but in a somewhat longer run. It was then October, it is now July, and the difference in the number of the degrees is easily accounted for by the season. By going more south and west in Capt. Brace, the water was raised to 67. when we found ourselves within the stream, it would at this season probably be upwards of 70. I therefore

fore conclude that we are within the influence of the heat, but not the current of the stream, and I am in hopes to find that we have had that eddy current in our favour.

August 1.

9 A. M.

Having the land in sight, we are confirmed in the supposition that a favourable current has carried the ship faster than the Captain reckoned.



APPENDIX.

NOTES TO THE MARITIME OBSERVATIONS.

N^o. I.

Extract from the Journal of an Officer on board the British ship of war Liverpool, in November and December, 1775, on the coast of Carolina and Virginia.

WHEN Cape Henry bore NW 160 leagues found a current setting to the southward at the rate of 10 or 12 miles per day, which continued so till Cape Henry bore WNW 89 or 90 leagues, then found a current setting to the NE at the rate of 32 or 34 miles per day, this current continued till within 33 or 30 leagues of the land on the above coasts, then it sets to the southward and westward, at the rate of 10 or 15 miles per day, till within 12 or 15 leagues of the land. This current which is only the eddy of the Gulph stream, sets mostly SW or as the land lies.

In lat. 37. 50. sounded, and had 65 fathoms, fine sand, being 25 leagues from the land. In the same latitude and only 26 leagues from the land, had no bottom, with 180 fathoms.

From

From lat. 35. 30. to lat. 37. 0. there are no soundings 20 leagues from the land, but at 19 leagues distance there are soundings in 60 fathoms, at 18 there are only 35 fathoms, and from thence gradual soundings to the shore.

From Cape Hatteras to Cape Henry, the ground is fine sand, and to the northward of Cape Henry, coarse sand with some shells among it.

Nº. II.

Extract from the Journal of an Officer on board the British ship of war Liverpool, between 26th September and 9th October, 1775.

IN lat. 45. 43. N long. 21. 20. W from Greenwich, found a current setting to the southward 12 to 15 miles per day, which continued till we made the island of Corvo, the north part of which is in lat. 39. 56. N and long. 31. 8. W from Greenwich by celestial observation, which agreed within 12 miles of the longitude per account, that being 30. 56. The variation of the compass off this Island is 18°. 19. W and in sailing to the southward and westward, it gradually diminished, till we arrived in lat. 29. 0. N long. 66. 40. where we had no variation.

Nº. III.

N^o. III.

*Extract from the Journal of an Officer on board the British
ship of war Liverpool.*

ON the 18th of October, 1775, in lat. 42. 4. N long. 10°. 8. W from the island of Corvo, it bearing S 75. E distant 156 leagues, the sea being then very smooth it was suddenly agitated into a short irregular sea (without any shift or increase of wind) such as is generally occasioned by currents, and the next day we found we were 30 miles to the southward of the reckoning. This current continued till the 22d of October, having then arrived in lat. 37. long. 13. 30. W. It set S by W $\frac{1}{2}$ W $1\frac{1}{2}$ miles per hour.

Having a fair wind, and a good observation every day, and also good astronomical observations for determining the longitude, we had the greatest reason to depend on the authenticity of the above.

 N^o. IV.

*Extract from the Journal of an Officer on board the British
ship of war Liverpool, July, August and September,
1775.*

THE bank from Cape Cod extends almost as far as Cape Sable, where it joins the banks of Nova Scotia deepening gradually from 20 to 50 or 55 fathoms,

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which

which depth there is in lat. 43. In crossing the bank between lat. 41. 41. and lat. 43. the bottom is very remarkable; on the outside it is fine sand, shoaling gradually for several leagues; on the middle of the bank, it is coarse sand or shingle with pebble stones; on the inside it is muddy with pieces of shells, and deepens suddenly from 45 or 48 to 150 or 160 fathoms.



N^o. V.

In lat. 44. 54. N long. 53. 19. W on board the British packet Chesterfield, Capt. Schuyler. July 10, 1790.

THE Captain caught a cod fish, and in a few minutes after it was opened and gutted, I put the thermometer into its belly, the instrument marked 39. when in air it was 57. and in water on the surface 52. Depth 46 fathoms.

In lat. 44. 52. N long. 54. 57. W. July 11, 1790.
The people caught several cod fish and hallabot, the thermometer was put into three cod fish and one hallabot successively, the instant they were hauled up, and the instrument marked 37. in every case. The air was at 57. and the water at the surface was 53. The first experiment

experiment was repeated after the fish was gutted, and it then marked one degree warmer. I thence concluded that the difference between the two experiments was owing to the time the fish was in the air before the trial, and that in all the instances the animal heat of the fish was about 16° . colder than the water at the surface; and as it seems natural, from analogy, to suppose that animal heat is at least as warm as the fluid in which the animal lives, I conclude that the water at the bottom was as cold as 37 . *i. e.* 16° . colder than at the surface. In a former voyage it was found by decisive experiment, that near the coast in very hot weather the water at the bottom in 18 fathoms was 12 degrees colder* than at the surface.

Another reason to suppose that the water was colder at bottom than the animal heat, was the great distention of the cods sounds when they were opened, although they had sent out innumerable bubbles of air in the passage up; the air, therefore, within the sound, must have been much more compressed, (either by cold or the power of the animal) below, than above where it was at 37 . Several fish that had been hauled up to the surface of the water, and then dropped from the hook, swam light on the surface till they recovered their vivacity,

* See my Journal of a voyage with Doctor Franklin, in the London Packet, Captain Truxton.

city, although they lost much air in coming up; the specific gravity was therefore much less than at bottom, and this was probably owing to the distention of the found. That fish rise and sink in the water, by this power of increasing and diminishing their bulk, and consequently their specific gravity, is well known to naturalists, but I was pleased to see the truth of that fact confirmed by these experiments.

JONATHAN WILLIAMS.

REPORT.



REPORT.

BY DON CIPRIANO VIMERCATI,

Director of the Marine Academies of Spain.

THE memoir of Jonathan Williams, on the use of the thermometer in the sea, has been transmitted to me, with his Majesty's orders, that I should examine it, give my sentiments upon it, and obtain a correct translation of it, in case I should consider it useful—This I have faithfully executed, adding thereto an exact copy of the chart containing the route in which the author made his observations, leaving some names of capes, islands, &c. in the English idiom, which appeared to me in most general use, and giving to others, for a similar reason, those which had first been Spanish, or permanently fixed or denominated in that language—and from the judgment I have formed on an attentive reading,

I DO REPORT,

That the experiments of Williams are made so minute, so progressive, and regular, and so analagous to those deducible from physical principles, universally admitted, concerning the continued action of heat and the distribution of it through all bodies, that they cannot but be
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an additional support to navigation, and a happy accession to the progress of the known hydrography.

That heat spreads and passes from one body to another contiguous to it, seeking as far as possible its equilibrium, is a fact asserted by the famous Boerhave, and since confirmed and acknowledged by all philosophers.

In this sense it is said, that the coldest body imbibes or absorbs a part of the heat of that which is less so. This distribution is equal, if the bodies are perfectly homogeneous, and they transfer from the one to the other equal quantities of the matter of heat* at regular periods, until the equilibrium is obtained: Or, more strictly speaking, there is a certain acceleration of movement in it when passing from one body to another; but this case, except in small masses, is either rare, or does not in fact exist in nature. Yet the effects of this matter and movement, approach nearer to it, in proportion as the bodies in which it acts are homogeneous. With the heterogeneous, this distribution is not uniform, and the action of the heat is slower, or accelerated in proportion to the impediments which one body opposes to another. In small bodies the difference is scarcely perceivable. This is proved by the experiments of Muschenbroek, (Lulof's edition from No. 1597 to 1600;)

* Caloric.

1600;) in very great masses upon the earth, for instance, mountains, or under the water, such as large banks, the difference is very sensible, the progress with which this distribution is made, being more or less slow, according to the various densities, or other local circumstances, though always drawing towards the equilibrium.

The abovementioned Muschenbroek, No. 1602, gives the two following observations, relative to the heat of the sea water, of which he treats very lightly, no doubt from the want of the facts to support him. The first was taken from Count Marfigli's history of the sea, which is, that the water of the ocean at the depth of 720 feet possesses the same degree of heat as the atmospheric air. The second is from Captain Henry Ellis, of the royal society of London, who in the *Philosophical Transactions*, Vol. 47, page 213, affirms, that marine water from the superficies to the depth of 3900 feet gradually becomes more cold, more salt, and consequently heavier; but from this depth to that of 5346 (as far as he could extend his experiments) preserved the same degree of heat, that is 53°. of Fahrenheit, being at the surface 84. As to the first quality of heat, which is the present object, let us compare this observation with the hypothesis of Williams, and with the general principle, in order to see whether it confirms or contradicts either of them.

But

But before we go into this comparison, it appears to me proper, that Ellis's observation may be seen, with the circumstances at full length, here to give an extract of a letter from him, inserted in those *transactions*, dated 7th of January, 1751, and addressed to the celebrated Hales, on board the ship Count of Halifax : to wit, " In
" my voyage, being in latitude 25'. 13". north and
" longitude 25'. 12". west. I made several experiments
" with the bucket sea-guage. I charged it and let it
" down in different depths from 360 to 5346 feet, and
" by means of a small thermometer, modelled by Fahrenheit's, constructed by Mr. Bird, which was placed
" in it, I discovered that the cold increased regularly,
" in proportion to the depths, till it descended to 3900
" feet; from whence the mercury in the thermometer
" came up at 53 degrees; and though I afterwards
" sunk it to the depth of 5346 feet, that is a mile and
" 66 feet, it came up no lower. The warmth of the
" water upon the surface, and that of the air, was at
" that time, by the thermometer, 84 degrees. I doubt
" not but that the water was a degree or two colder,
" when it entered the bucket, at the greatest depth,
" but in coming up, had acquired some warmth, for I
" found that the water which came up in the bucket,
" having stood 43 minutes in the air (the time of winding it up) the mercury rose above 5 degrees." Thus far the observation of Ellis, and he adds: " This experiment

“ periment which seemed at first but mere food for curiosity, because, in the interim, very useful to us. By its means we supplied our cold bath, and cooled our wines or water at pleasure, which is vastly agreeable to us in this burning climate.” He concludes: “ I intend in our passage to the West Indies, to sound a mile deeper than I have done, having a sufficient quantity of line. But I cannot attempt your method to find the depth of the sea, for want of apparatus.”

To this letter, which Hales communicated to the society, he added one from himself to the president, in which he describes the construction of the sea gauge, used in the experiments, and speaks thus: “ The bucket sea gauge which he (Ellis) mentions, and which I provided for him, to find the different degrees of coolness and saltness of the sea, at different depths, was a common household pail or bucket, with two heads in it, which heads had each a round hole in the middle near four inches diameter, which were covered with valves, which open upwards; and that they might both open and shut together, there was a small iron rod fixed to the upper part of the lower valve, and at the other end, to the under part of the upper valve: so that, as the bucket descended, with its sinking weight into the sea, both the valves opened by the force of the water which had by that means a free passage through the bucket. But

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“ when

“ when the bucket was drawn up, then both the valves
“ were shut, by the force of the water, at the upper
“ part of the bucket: by which means the bucket was
“ brought up full of the lowest water, to which it had
“ descended. When the bucket was drawn up, the
“ hole at the bottom was stopped with cork to keep the
“ water in, when the valves were opened, to come at
“ the thermometer, which being tied to an upright
“ stick, could readily be unfastened, by pulling out a
“ loose nail, which went into the upper end of the
“ stick, which was fastened at its lower end in the same
“ manner. But great care must be taken to make an
“ observation of the degree the mercury stands at, before the lower part of the thermometer is taken out
“ of the water; else it would immediately be altered
“ by the different temperature of the air. In order to
“ keep the bucket in a right position there are four
“ cords fixed to it, which reach about three feet below
“ it, to which the sinking weight is to be fixed.”

Thus far Doctor Hales. I have, out of compliment to the ingenuity and simplicity discovered in this invention, digressed for the purpose of introducing these extracts.

Having now come to what may be deduced from the above observation, on comparing it with those of Williams, as well as with the general principle of the communication

munication of heat, the following are the result: The experiment recited by Williams (appendix No. V.) is, that the water being at the surface 52 degrees of the same scale of Fahrenheit, and the depth, by sounding 46 fathoms, the thermometer introduced into the belly of a fish indicated a heat of 37 degrees, which might probably be considered as nearly the degree of the warmth of the water at the bottom. The difference between it and that at the surface are 15 degrees, and this was 5°. lower than that of the atmosphere, which was at 57°. So that whether the bottom absorbs the heat, according to the general principle, or whether the air, communicating itself more slowly in proportion as the water is deepened, it successively becomes more cool: from one of these causes, or from a combination of both, arose at 46 fathoms deep, the difference of 15 degrees, with respect to the surface, and of 20°, with respect to the air. But in these differences arise a notable diversity, compared with that resulting from Ellis's observation. Because,

1. The air and the superficies of the water were of equal degrees of warmth.

2. The 3900 feet, which may be supposed to be nearly 650 fathoms, the difference of the superficies and of the air, and the greatest depth of the water was 31 degrees.

3. From that to 5346 feet, or nearly 890 fathoms, as far as is ascertained by Ellis, the heat was the same.

Notwithstanding, on examining the circumstances, of both observations, I meet with no great difficulty in reconciling them; and conceive, that the variations may be attributed to the same causes, diversely combined.

In that of Williams, the latitude was $44^{\circ} 52'$ north, and the time, the 11th July, in which the atmosphere is less warm than at the end of summer. That of Ellis, was in the middle of the torrid zone, and the time not expressly determined; and though the date of his letter is the 7th of January, which, in that latitude is one of the winter months, yet we collect from the use made of the cold deep water for bathing and cooling liquors, that the season was exceedingly hot. This, together with the frequent equinoctial calms, and the considerable part of the year during which the sun continues perpendicularly over those climates, must produce little or no difference in the circumambient air and the surface of the water.

And if in July, and in latitude $44^{\circ} 52'$ north, this difference was only 5 degrees, it is not extraordinary if it should be insensible near the line.

Besides, the difference in the superficies of the deep water, is from 15. to 16. in that of Williams, and 31. in

in that of Ellis, which is the double of the former, and the depth of the latter fourteen times greater than in the observation of the other. Hence it appears the result should be, that the excesses of the cold preserve a due proportion to that of the depth. In such case the excess of the heat at the surface, beyond that of deep water, must be fourteen times greater in one observation than in the other. The water under the line, and in the depth of 3900 feet, instead of being at 53° . above the naught of Fahrenheit, would be 126° . under this limit, which is 126° . colder than that produced by the mixture of *snow and sal amoniac*; and the mercury (were it not prevented from arriving at this depth from the water's being much earlier converted into the hardest ice) would mark that degree. But this point might be expected whenever there existed a concurrence of all the other circumstances;—and if the waters of the ocean were heated by the warmth of the atmosphere and the sun alone, then the diffusion of this heat would decrease in the water, in proportion to its depth, and in high latitudes and climates considerably cold, the sea would always freeze in winter, not only on the surface, as in rivers, but in its whole depth: This being a necessary consequence of the general principle in this case. But such a case does not exist: Because, although one of the general causes of the heat of the earth and of the water of the ocean, is the action of
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the rays of the sun, which cross the atmosphere, there is doubtless another concurring with it, which is the internal heat of the globe, supported by subterraneous fires, and the principle of heat put in action, and variously distributed throughout the mass: And perhaps some other cause, of which we are ignorant. All these modified in an infinite variety of ways diffuse the heat as much as possible through every part, and where it meets with opposition, or does not sufficiently pervade the matters to maintain their respective fluidity, there remain congealed.

In the case of which we treat, 31 degrees of heat, diminished from the surface to 3900 feet, in a latitude, in which, from the respective position of the sun, the heat of the atmosphere and of the surface was very great, and should vary but little in the equal alternative of days and nights; whence the bottom which might absorb it and augment the cold, was very far distant, accounts, nearly, for the diminution of 15 degrees in a latitude of $44^{\circ} 52'$. and wherein by the small depth the bottom absorbed a great part. This diversity of circumstances manifests, sufficiently, that the cold must augment in 46 fathoms or 276 feet, in a proportion many times greater than that to which it augmented in 650 fathoms, or 3900 feet.

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The difficulty of explaining the constant temperature of the water at 53° . from 3900 to 5346 feet, is greater; and it cannot be denied that the phenomenon has something singular in it, in case it be ascertained that the thermometer effectively falls to that depth; nor shall I attempt to explain it, as nothing could be urged but upon general principles.

However, the above observations do not destroy the experiments and hypothesis of Williams. For when the thermometer is used in seas immediately under the line, the facts must be viewed in relation to that position, which may be very different from those we have seen in the voyages of that observer. In them it is stated, that at sundry periods of the year the heat of the water on the surface and that of the air were different and proportionate to the influence of the season; but the difference between them was respectively the same in the same latitudes, and always very sensibly indicated the vicinity of banks and coasts.

Under water this difference was insensible at the time of Ellis's observation, in a sea of great depth. What this would be in seas interspersed with eminences, banks, islands and channels, or encompassed by the coasts in the same latitude, who could decide unless he were to take experience for his guide? For the temerity would be great to apply to this position of the globe that which has been observed in very distant latitudes.

For

For the same reason I do not speak of the experiments of Marfigli, already cited, because, they are not circumstantial, and not having in my hands his history of the sea, I can form no conclusion upon them; and what he does say, if it be certain, is that it necessarily depends on local causes, about which one cannot even hazard a conjecture.

Finally, from all that has been said, the result on the memoir of Williams, is, that the application of the thermometer, to navigation, is a happy accession and an additional aid, which, from the facility of its use, it might be expedient to promote, but being in its infancy, and hitherto confined to experiments made on a contracted scale, it would be proper to extend them to other climes and seas, in order to perfect the same, so far as to notice the deviations, and from them to form tables of the results, together with rules accommodated to the various seasons of the globe. A similar plan was begun on the variation of the needle, whence to form charts, which might serve for determining, nearly, the longitude by the known change. This project, however, being supplied with advantage by other means, has been abandoned from the deviations observed in the lines of variation. According to the idea of Williams, probably this ought not to have happened. The facts observed in a certain limit of sea, and latitude, will always be the same, with the single difference, arising only from the diversity of seasons.

The

The celestial observations, which give the position of the ship, will never give the depth of the water or notice of approaching danger from an unknown coast. In fine, in a matter which is of so much importance to humanity, the light manifested in this memoir should be pursued whilst it remains unobserved by a multiplicity of irregularities, or other obstacles which would render the pursuit impossible.

(Signed) CIPRIANO VIMERCATI,
Director of the Marine Academies.

ISLE OF LEON, 20th Dec. 1793.



A Thermometrical Journal of the temperature of the atmosphere and sea, on a voyage to and from Oporto, with explanatory observations thereon. In a letter to DAVID RITTENHOUSE, L. L. D. President of the American Philosophical Society.

SIR,

Read Sept.
21st, 1792.

ON the 15th of June last Capt. William Billings of this city, commander of the ship Apollo, presented the journals of his voyages to and from Oporto, for the inspection of the American Philosophical Society. As they were not accompanied by any explanatory memoir, I have extracted from them what alone differs from sea reckoning in general, and inclose a thermometrical journal of the temperature of the atmosphere and sea, which evidently appears to be the object of the communication. As it was proper to shew that these observations were not imaginary, and had arisen in the course of his voyages, Capt. Billings presented his whole journals, consisting of 73 pages in folio, with all the detail of a log book, which in original are deposited among the society's papers.*

As

* The temperature of the water was tried several times every day, but in this extract it was thought proper only to notice the important changes a succession of similar results being thought unnecessary.

As the experiments of this intelligent navigator, appear to be repetitions of those I made ~~near~~ two years before, which are related in my memoir, page 11, I beg leave to make the following observations on them:

By these journals it appears that in June, 1791, the water on the coast was at the temperature of 61° . by Fahrenheit, and in the Gulph stream at 77° . By my journals it will be found that in November, 1789, the water on the coast was at 47° . and in the Gulph stream at 70° . viz.

By Capt. Billings,	By my experiments	diff. between
1791, June, coast, 61	1789, Nov. coast, 47	June and Nov.
do. stream, 77	do. stream, 70	14° .
		7
do. stream warmer, 16	do. stream warmer, 23	

Hence it may be concluded that although this difference of heat is more remarkable in winter than in summer, yet it is sufficient at all times to guide navigators, so as to take the benefit of its current in going from, and to avoid its opposition in coming to America. In the latter case, it has this additional convenience in correcting a reckoning; for if a navigator can, by this means, know the moment he is within the stream, he knows at the same moment his relative situation as to the coast; and if, by repeated experiment, this mode of correction should be found solid, it amounts, in effect, to

a certainty of the longitude, at the precise time when it is important to be accurate.

Capt. Billings's course being nearly along the stream, he found only such alteration in the heat of the water as may be accounted for by the cooling of the stream itself, in its course to the northward, till he came to lat. 39. 0. N long. 56. 0. W (a-breast of the banks of Newfoundland) when the mercury fell 10°. Doctor Franklin, in November, 1776, on board of the *Reprisal*, in lat. 41. N, long. 46. W, found about the same difference; but the *Reprisal* had kept a course farther south and came into this cool water in a NNE direction; while Captain Billings being farther north, came in an easterly direction, and of course might be as much within the influence of that chain of banks which extends from the longitude 45. W along the American coast, as the *Reprisal* was when so much farther to the eastward. In November 1789, I found the same difference in lat. 40. N long. 49. W, after sailing in a direction about NE; and a line being drawn from the place where Captain Billings's change happened, to that where Doctor Franklin's thermometer fell, (in a direction about ENE) would nearly intersect the place where I observed the same alteration: this is about the sweep of the banks, known by frequent sounding, as will be found by consulting the best charts.—By the coincidence of these three journals, at so great a distance of time, and without

out any connection with each other, this important fact seems to be established. *A navigator may discover his approach towards objects of danger, when he is at such a distance as to be able easily to avoid them, by attentively examining the temperature of the sea.*

After having passed the banks Captain Billings found but little difference during 18 days sail, till he came near the European coast. The same uniformity appears in my journal on a voyage to England, page 23.

Captain Billings found the water to grow cooler three days before he made the land, and the mercury fell gradually from 65. to 60°. when the land appeared; This was in June. In November I found on approaching the English coast a gradual fall from 53. to 48°. and then we struck soundings. Here the difference between the sea and coast water was in both cases the same, though the heat of both varied with the season.

Returning from Oporto, Captain Billings marked his approach to, and departure from the western islands by the changes of his thermometer, but in this case the difference was small; because, owing to the climate and size of these islands, the land cannot be so cold as a northern continent naturally must be. Indeed, the usefulness of the thermometer seems to be applicable to the more dangerous situations, and not to islands in warm climates; I should suppose, for obvious reasons,
that

that the changes would not be great about the islands situated between the tropics. The shore of these islands is generally bold, and the land being very high, may be seen at a great distance. The climate is not subject to fogs, snow storms, islands of ice, long nights, &c. so that, except hurricanes, (which are more fatal to ships in port than at sea) there seems to be but little danger in such navigation.

After leaving the western islands, Captain Billings steered to the westward, being in nearly the same latitude on the 30th ($37^{\circ}.47^{\circ}.N$) that he was on the 17th of August. ($37^{\circ}.53^{\circ}.N$) But during the intermediate time he was driven, as winds prevailed, in a zig zag course, as far north as $39^{\circ}.4. N$, and as far south as $36^{\circ}.26. N$. It appears also during this time that his thermometer varied from 1° . to 5° .; but it is to be remarked that there is a medium in his thermometrical variations answering to the medium of his latitude. When he was in $39^{\circ}.4.$ the thermometer marked 75° . and when in $36^{\circ}.26.$ it also marked 75° . but when in $38^{\circ}.12.$ it marked 70° . Now considering that he had the warm influence of the Gulph stream to the northward, and that the ocean water to the southward must naturally be warmer than that more north, out of the stream, there seems to be a perfect agreement between theory and fact with regard to the usefulness of the thermometer in discovering the course of this current.

rent. The same thing occurred in the course of my passage in the London packet with Doctor Franklin, (see Vol. 2, page 329, of the Transactions of this Society) in June 1785. The mean there was 73, while to the northward and southward the thermometer marked 77.

Returning towards the coast of America, Captain Billings discovered his passage across the Gulph stream by a sudden fall in the mercury of 5° . from noon to night, and about 5° . farther west, by a further fall in the space of 8 hours run, he discovered the coast, where he got soundings, before he saw the land.

The usefulness of the thermometer as a nautical instrument is not confined to the discovery of an approach towards objects of danger *known to exist*; but it may, if attended to, discover others *not at present supposed to exist*, against which a navigator cannot be on his guard. Several charts, particularly one made by Governor Pownall, in September, 1787, point out rocks and breakers in the middle of the ocean; some are said to be uncertain, others have been seen but once, and preserve the names of their supposed discoverers. These facts are generally doubted, and by some mariners have been ridiculed; but it should be considered that in every instance where the discovery of these hidden dangers have been fatal, no one could escape to tell the melancholy tale,

tale, and surely the number of missing ships justifies a conjecture that such misfortunes have happened, and ought to influence every navigator to make accurate observations on the temperature of the sea during the *whole* of his voyage.

A gentleman of undoubted veracity related to me some time since, the following fact, which I mention on account of its aptitude to this subject.

On a voyage from the West-Indies to England, the small vessel he was in, touched at Bermuda. On leaving that island, having fine weather and a smooth sea, they sailed along a ridge of rocks, seeing the bottom very plainly all the time, till the island was out of sight; in this place they spoke a large ship, the Captain of which, had no idea of his situation; he had not noticed the bottom, and was sailing in full confidence of being far from danger. On being desired to look over the side of his ship, the whole crew was in the utmost consternation, and hove the ship too, with all her sails set. He was soon informed of his true longitude, and took a new departure. Had this Captain kept a thermometrical journal he would not, probably, have been so deceived, and had he at this time been in a gale of wind, his error might have been fatal. Every body in this city remembers the dreadful catastrophe of the ship Faithful Steward, which was lost on this coast, with
near

near 500 people on board, about seven years since. The Captain was so sure of having sufficient sea room, that he did not think of sounding, the weather was not boisterous and had he known his situation he might have stood off during the night. But fearless of a danger he did not know, he stood on with full sails, and was in an instant lost; I think there were not above twenty souls saved. A thermometer regularly used would have given warning in time, and probably have saved these lives.

The impression such events have made on my mind, has induced me to be thus particular, and I the more readily do justice to the judicious example given to other Captains, by Captain Billings, because I think the observations of a mariner, are more likely to be attended to by mariners, than any instruction given by a landman. I think besides, that the merit of Captain Billings, ought to be rewarded, by a publication of his laudable conduct, that he may enjoy the reputation to which he is justly entitled.

I am with great respect, Sir,

Your most obedient and .

Most humble Servant,

JONATHAN WILLIAMS.

One of the Secretaries of the American Philosophical Society.

A Thermometrical Journal of the temperature of the atmosphere and sea,
on a passage from Philadelphia to Oporto, in the Ship Apollo.

By Captain WILLIAM BILLINGS.

Dates. 1791.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
June 6	Sun rise.	38 56	75 7		61
	2 P. M.	38 38	74 28		66
	Sun set.			65	66
8	10 A. M.				70
	Noon.	37 18	72 34	75	72
10	Noon.	38 3	68 49	73	77
11	Noon.	38 51	65 57	66	75
12	Noon.	39 2	63 22	71	71
14	Noon.	39 11	56 48		62
15	Noon.	39 37	53 43	71	65
July 2	Noon.	40 16	15 34	68	65
3	Noon.	40 5	13 23	68	64
4	Noon.	40 28	11 13	68	63
5	2 P. M.			68	63
	7 P. M.				60
	8 A. M.				57
	Noon.				55

NOTES.

June 6. Off Cape Henlopen.—N. B. The thermometer is on Fahrenheit's scale and the longitude west from London.—The days are reckoned to begin at noon and to end at the succeeding noon according to the usage of navigators.

June 8—10 A. M. Being the first alteration in the heat of the water after leaving the coast, it is supposed we entered the gulph stream. The course is not across, but rather along this current, somewhat diagonally however.

June 10—noon. It is supposed we are in the middle of the Gulph stream.

June 14—noon. This sudden fall of 9°. is supposed to be owing to the influence of the banks of Newfoundland which bear about N.

From the the 15th of June to the 2d of July, the variations in the heat of the sea water do not exceed two degrees, they need not therefore be noticed.

July 4. The water appears to have changed colour.

July 5—7 P. M. Land in sight, but frequently obscured by fog.

July 6—8 A. M. Land distant about 6 leagues.—Noon. Land distant about 2 leagues, being the high land of Braganca Nova.

OBSERVATIONS.

63

A Thermometrical Journal of the temperature of the atmosphere and sea,
on a passage from Oporto to Philadelphia, in the ship Apollo.

By Captain WILLIAM BILLINGS.

Dates. 1791.	Time.	Places in at Noon.		Temper. of	
		Lat. N.	Long. W.	Air.	Water.
Aug. 4	10 A. M.				57
	Noon.	41 7	9 4		60
5	Noon.	40 39	13 6	69	61
6	8 A. M.			69	65
	Noon.	40 35	17 6	69	67
7	10 P. M.	40 29	20 24	68	68
8	Noon.	40 24	22 1	69	68
9	Noon.	41 0	22 49	68	68
10	Noon.	40 13	22 39	68	68
11	Noon.	38 42	24 02	69	71
	10 P. M.				70
	Midnight				69
12	Noon.	37 57	24 55	72	70
14	Noon.	38 45	27 7	73	71
15	2 P. M.			72	70
	Sun fet.			72	69
	Sun rife.				68
16	2 P. M.	38 24	27 51	73	70
	Sun fet.				69
	10 P. M.				68
	Midnight				69
	Noon.	37 53	27 20	73	71
17	10 P. M.			70	72
	Noon.	37 7	27 39		73
18	Noon.	36 36	28 44		73
19	Noon.	36 9	31 39		73
20	Noon.	36 26	34 31	74	75
21	10 P. M.			74	74
	10 A. M.				70
	Noon.				69
22	Noon.	38 24	36 48		69
23	Noon.	38 43	38 49	74	73
24	10 P. M.	38 43	38 49	74	73
	Noon.	38 44	41 32		71
25	Noon.	39 04	44 17		75
26	Noon.	38 56	46 44		75
27	Noon.	38 12	50 10		70
28	Noon.	37 2	51 28		75
29	Noon.	38 8	52 31	74	74
30	Noon.	37 47	53 20	74	75
31	10 P. M.			72	70
	Noon.	39 20	53 20		69
Sept. 1	Noon.	40 41	54 7	71	74
2	Midnight			72	74

A Thermometrical Journal of the temperature of the atmosphere and sea,
on a passage from Oporto to Philadelphia, in the ship Apollo.

By Captain WILLIAM BILLINGS.

(Continued.)

Dates. 1791.	Time.	Places in at Noon.		Temp. of	
		Lat. N.	Long. W.	Air.	Water.
Sept. 2	Noon.	40 57	55 26	70	72
3	Midnight				71
	Noon.	40 56	57 51	70	73
4	Noon.	39 10	59 18	74	74
5	Noon.	39 17	61 11	74	76
6	Midnight				77
	Noon.	40 6	63 20	74	78
7	Noon.	40 36	66 3		75
8	Noon.	40 1	67 23	73	77
9	10 P. M.			71	73
	Midnight				72
	4 A. M.				71
	Noon.	39 29	71 17		73
10	Noon.	39 19	72 8	73	73
11	Noon.	39 4	72 33	74	75
12	Noon.	38 57	73 21	74	74
13	Noon.	38 53	72 31	74	75
14	Noon.	39 21	73 31	75	73
15	6 P. M.			74	69
	8 A. M.				68

NOTES:

August 4—10 A. M. Port barr : bearing ESE distant 7 leagues.

August 10.—But about half of degree difference of latitude for these 5 days past, and little or no change in the temperature of the sea.

August 11—noon. 1 and $\frac{1}{2}$ degree southing water 3°. warmer.—4 P. M. made the island St. Michael; island, dist. 4 leagues; tacked and stood off.—5 A. M. tacked and stood to the southward.

August 15—4 P. M. Made the island Tercera,

August 16—Sun rise. Near Tercera, St. George's, and Pico in sight.—10 P. M. Close in with St. George's.

August 17—noon. Land out of sight.

Sept. 6—Midnight. This rise indicates the Gulph stream.

Sept. 9—10 P. M. This fall indicates the western side of the Gulph stream.

Sept. 15—8 A. M. Sounded in 25 fathoms.

DIRECTIONS

DIRECTIONS
FOR
USING
THE THERMOMETER
IN
NAVIGATION,
WITH
Miscellaneous Remarks.

ADDRESSED

To all Naval Commanders.



“Diligence and Attention are the parents of good luck.”

Poor Richard.

ADVERTISEMENT.

☞ *THE* writer means to speak to *ALL* Navigators; it is hoped therefore, that those who find the following directions unnecessary, will pardon the repetition of what they well understand, in consideration for those who may not be so well informed.



DIRECTIONS TO NAVIGATORS.

TAKE with you at least three thermometers, for fear of accidents. Let them be kept in one place some days previous to your sailing, in order to try their uniformity. The plate should be of ivory or metal, for wood will swell at sea, and as the glass tube will not yield, it is for this reason very liable to break; bell metal is the best. Let the instrument be fixed in a square metal box, the bottom of which, as high as the mark 30°. should be water tight, so that in examining the degree of heat, the ball may be kept in the water; the remainder of the length should be open in front, with only two or three cross bars to ward off any accidental blow, like the thermometer used by brewers. Fix one instrument in some part of the ship in the shade, and in open air; but as much out of the wind, and in as dry a place as possible. The after part of one of the after staunchions, under the quarter rail may answer, if no better place can be found.

Let the second instrument be neatly slung with a sufficiency of line to allow it to tow in the dead water of the wake.

Put

Put the third away safely in your chest, to be ready to supply the place of either of the others.

When you make your observations, begin by noting the state of the air from the instrument on deck. Throw the other out of the cabin window, and let it tow two or three minutes, then draw it up and examine it the instant you can bring it to your eye, with the ball *still in water*, and note the degree: This is a necessary precaution for the mercury will soon fall when the thermometer is wet, especially if exposed to any wind. When you examine the water at night take care not to heat the instrument by a candle which should be always in a lantern; do not touch the tube, nor breathe upon it, while you examine it; least you should communicate heat by the touch, or take it away by causing an evaporation, which is the effect of blowing upon a wet thermometer.

Endeavour to make all your experiments in an uniform manner, do not try the water one day out of the cabin windows, another over the side, or in a bucket; but keep to one steady rule; it is not so material which way you do it, as it is to do it always the same way. If a bucket be used let it tow long enough to take away its heat, for the cook may have had it full of hot water.

Pay constant attention to the changes in the temperature of the air, and compare them daily with the changes in that of the water. This will account to you for the alterations on the surface of the sea, (especially in calm weather) which naturally follow the alterations in the incumbent atmosphere: The difference between deep water and soundings will, under the same temperature of the atmosphere, still be the same. If, when in open sea, you should perceive a small change in the water, without being able to account for it by an alteration of latitude, or of the weather, you may suspect a current from the northward if colder, from the southward if warmer; and as circumstances may permit, you will do well to ascertain it.

Compare your observations from time to time with those mentioned in the journals and noted on the chart, and if you find any difference when in the same situation, repeat your experiments, so as to be sure that the error is not on your side.

Although it is not pretended to give accurate accounts, from the few experiments that have been made, it is presumed that the following will be found near the truth.

On the COAST of EUROPE.

From the channel of England to the Tagus it will be generally found, that the water over soundings is about

three degrees colder than at sea. And that the first symptom of soundings is at a great distance from the land, for the coast (unlike that of America) approaches from an imperceptible depth to soundings so gradually that it is not easy to say when you can get the ground. But were you to approach the rocks of Scilly, western coast of Ireland, Orkneys, &c. the alteration would probably be sudden and very decisive.

On the COAST of NORTH AMERICA.

At the edge of the Grand bank the water is 5 degrees colder than the deep ocean to the eastward. The highest part of the Grand bank is 10. colder still, or 15. colder than the ocean eastward.

As the banks deepen between them and the coast of Nova Scotia, the water grows about 6°. warmer till you get quite within them, when it rises to about the temperature of the deep ocean without; on soundings the mercury will again fall to the temperature of the inner banks. So that in coming from the eastward a fall of 5°. will indicate your entrance on the edge of the Grand bank, and a further fall of 10°. will indicate your being in soundings. Passing the summit of the banks a rise of 6°. will show the western edge of the Grand bank, and a further rise to the temperature of the deep ocean without will indicate the deep water within the banks. When the mercury falls again to the temperature of the inner banks, you strike soundings on the coast of Nova Scotia.

An important observation occurs here. The isle of Sable is a little bank of sand above water, which receives heat readily from a hot sun and communicates it rapidly to the shoals under water, upon the principle mentioned as to land-locked places. If therefore you come too near that island in hot weather the thermometer will probably vary from these rules, in that case you may get bottom. If however, the previous observations are well made, you need not be in danger, for you can by your meridian altitude, shape your course as far to the northward or southward as you choose.

On the coast of New England off Cape Cod, the water out of soundings is 8° . or 10° . warmer than in soundings, and in the stream it is about 8° . warmer still: So that in coming from the eastward a fall of 8 degrees, will indicate your leaving the stream, and a further fall of 8 degrees, will indicate your being on soundings.

On the coast from Cape Henlopen to Cape Henry, the water out of soundings is 5 degrees warmer than in soundings, and in the stream about 5 degrees warmer still: So that in coming from the eastward a fall of 6 degrees will indicate your leaving the stream, and a further fall of 5 degrees will give notice of soundings.

By this sort of comparison a Navigator may readily ascertain when he leaves the stream and enters on soundings.

foundings. It is not presumed to speak positively as to the degrees, except where it has been proved by experiment.

A short time since, the writer met with an excellent meteorological work, entitled "An estimate of the temperature of different latitudes." By Richard Kirwan, Esq. F. R. S. a celebrated English philosopher, who has enriched the fund of science with several useful works. It is difficult to make an extract from this book without injury, because the whole is so interesting, that to do it justice all should be read.

The note D is subjoined to shew how necessary it is to combine a knowledge of the sea with that of the atmosphere, and to stimulate Navigators to make numerous and accurate observations.

On CURRENTS, &c.

As to the course of the stream, its eddy and other currents in the Atlantic ocean, it is proper to quote the testimony of others, before conclusions are presumed to be drawn from the writer's own observations. To place these in a clear point of view, arrows are made on the chart indicating the names of the observers. Thus the arrows L mark the currents described in the extracts of a journal kept on board the British ship of war *Liverpool*, in the appendix, page 35. The arrows T mark the eddy within the Gulph stream, mentioned by
Capt.

Capt. Truxton in the subjoined note A. The arrows G mark the currents observed by Sir Erasmus Gower of the British ship of war Lion, according to the notes B and C; and the arrows M mark the currents observed by Capt. Mackintosh of the English East India company's ship Hindostan, according to note C. The other arrows are taken from the observations mentioned in the foregoing journals with the concurrence of the Captains on board of whose ships they were made.

With this testimony before us, and with the authority of Doctor Franklin for the accumulation of water by the power of steady and uniform winds, let us turn our attention to the tropical regions.

The diurnal revolution of the globe, would naturally cause an apparent current of air from the eastward, if there were no other cause, for the atmosphere not being absolutely confined to the surface, does not so immediately partake of that motion. This is more sensible about the equator, not only because it being the largest circle the diurnal motion is greater there, but the various causes of wind in every direction do not exist so strongly in the torrid, as in the temperate and frigid zones. But there constantly exists a cause of wind from the north on one side, and from the south on the other side of the line where the sun is vertical, owing to the rarification of the air by heat, which
the

the air from the northern and southern regions is constantly rushing in to supply. It is a fact well known to all Navigators, that the southern trade winds are composed of southern and eastern breezes; and the northern trade winds are composed of northern and eastern breezes; when those are of equal strength, the wind blows exactly NE on one side, and SE on the other side of the before mentioned line. But at all times it blows between these points, except in case of a tornado or hurricane: These winds according to Doctor Franklin's observations, force the water into the gulph of Florida, which issuing thence round the cape and through the Bahama islands, make our Gulph stream.

This water so driven from the eastward across the Atlantic to the gulph of Florida, must leave a vacancy for other water to be constantly coming in to supply its place. Do we not therefore find that the southern currents marked by Sir Erasmus Gower, Capt. Mackintosh and others, are a perfectly natural and infallible consequence of the foregoing theory.

It may not be amiss in this place to note the constant current into the Mediterranean. Why, it may be asked, is there not a reflux from that sea upon the same principle as we find a reflux from the gulph of Florida? This apparent phenomenon becomes, from self-evident principles, a natural event, when we consider the following

following facts. The climate of the Mediterranean sea must occasion great evaporation from its surface; the prevailing winds, from the causes instanced in the theory of the trade winds, must carry this evaporation over the African high lands, where it serves to form those rainy seasons for which that country is so remarkable, and runs into other seas; some indeed is returned by the Nile, but this is too small a quantity to supply the waste, for that is the only great river in the whole of its southern and eastern borders. The evaporation that may occasionally be directed eastward and southward, when it falls in rain, forms rivers which are lost in the Persian gulph or the Red sea, while the rivers on the northern side of the Mediterranean only supply the evaporation of the gulphs, bays, &c. into which they run; and the Black sea and Archipelago have occasion for all the water that runs into them to supply their own evaporation. Hence the Mediterranean must have a constant supply from the Atlantic to keep up its level with that ocean, and hence there is a constant current running into it. The gulph of Florida on the contrary receives from our western mountains an immense quantity of water by means of the Mississippi and other rivers, which more than supply its evaporation, and make the stream so much the stronger.

Little need be said about the eddy current, because every man who has rowed along shore in a river, or is in any respect acquainted with the tides must understand

it,

it, and that such an eddy exists in the Gulph stream, is proved by Capt. Truxton's observations in the note A, and the instances mentioned in the foregoing memoirs of ships being farther a-head than they were supposed by reckoning to be. When the stream has passed the banks of Newfoundland there is no other obstacle to check its course, it therefore naturally spreads itself in such directions as tend to the common level: We have already seen, that in a direction from the western islands to the Canaries there is a constant current; and must not that invite other water from the northward and westward of it to supply its place? May we not hence conclude that the Gulph stream makes a sweep in the direction described, only losing its name of stream, as it also loses (on the north side at least) its distinctive quality of heat: Indeed it is probable that as it turns to the southward into warmer water, it may be discovered by its want of heat, in comparison to the waters of southern climates, until the equilibrium of heat is restored.

The currents so common among the West India islands are probably the termination of the sweep of currents just described; and when the gulph of Florida discharges the water, it again becomes the Gulph stream. The importance of knowing how near to the coast a ship may venture, and how to distinguish the Gulph stream from the water between it and the coast is immense when applied to our coasting trade; for by this
advantage

advantage we can be sure of a favorable current either way, and a small vessel might make a short voyage from Halifax to Georgia, which is thought by some a longer one than to Europe. Suppose you had the wind a-head all the way. Take your departure and stand for the stream; as soon as you find the water to increase in heat about half as much as you know it would when in the stream; heave about and stand for the coast, you will infallibly discover the edge of soundings by the cooling of the water; then stand off again, and so on to the end of the voyage, when it is almost certain that the distance would be run in a shorter time than if there were no stream; for you would have a favorable inside or eddy current. On the return passage, take your departure and run off till you get into the hottest water, which will be the middle of the stream, and take the advantage of its current.

The following fact may serve to illustrate the propriety of these directions: In June last the mail packet for Charleston had twenty-five days passage in going, but returned in seven. The Captain accounted for this by having calms, or very light airs, and a northerly current. This was the true cause. He was in the middle of the stream, where there generally are calms or light airs: The edges only, which come in contact with colder regions, being tempestuous. After being in the latitude of Cape Hatteras, he found himself in that of Cape Henry. The vessel however, got there at last; and on the return voyage the Captain steered the same

course back again, and with the same light airs he performed the voyage in seven days. Had this Captain known the use of the thermometer, need he have been much longer in going than in coming?

A safe coasting trade is at all times an object for this country, but in war time the benefit is immense. We might convey supplies from one end to the other of our coast, by keeping just on the edge of soundings, where (always knowing the true bearings and distances of the land, which a foreign enemy might not know) our vessels could by steering for the land, put an end to a chase which through fear of danger, an enemy would probably be obliged to abandon.

JONATHAN WILLIAMS.

NOTES,

NOTES &c.



Extract from Truxton's Remarks, Instructions, and Examples.

“THE direction or course of the Florida Gulph stream may also be relied on, *as I often tried its rate of going, by anchoring a boat in a calm (with a rope made fast to an iron pot, the rope from 150 to 200 fathoms in length, and the pot from 18 to 25 inches in diameter, according to the size of the boat) and heaving the log, whereby its rate of going was ascertained, and found to be seldom less than one knot, and never more than two knots and a half per hour; that is to the northward of Cape Hatteras; but to the southward and westward of that Cape, it no doubt often runs much stronger; and the nearer the channel between Florida and the Bahamas, the stronger of course. The width of this stream I have fixed also, by trying the current; and, when opportunities offered, in passing or repassing it, by making observations of the heavenly bodies: Add to which, I have been attentive in ascertaining the temperature of the water, and comparing it with that of the air, as recommended

* See Truxton's chart.

mended by that great philosopher, the late Dr. Franklin.† The temperature of the air and water, without the stream, is generally about the same; that is, the difference seldom exceeds two or three degrees: Sometimes the air is the warmest; at other times the water."

"In the stream, the water is always much warmer than the air: indeed, I have known it ten degrees warmer; but so soon as you get within the stream, the water becomes colder than the air; and the more so, as you get on soundings, and approach the shore. If mariners, who have not the opportunity of determining their longitude by celestial observations, will only carry with them a good thermometer, and try the temperature of the water, and compare it with that of the air every two hours, they may always know when they come into, or go out of, the Gulph stream: Indeed, I always made a practice, when at sea, of comparing the temperature of the air and water daily, and often very frequently throughout the day during my voyage; whereby I immediately discovered any thing of a current that was going, and afterwards found its strength and direction by observations for the latitude and longitude. It is of the utmost consequence, in making a passage to
and

† The reader will perceive by the foregoing observations, that besides the comparison of the temperature of the air, with that of the water, it is proper to compare the heat of the water in different places one with another.

and from Europe, to be acquainted with this Gulph stream; as by keeping in it, when bound eastward, you shorten your voyage; and by avoiding it when returning to the westward, you facilitate it inconceivably; so much so, that I have frequently when bound from Europe to this country, spoke European ships, unacquainted with the strength and extent of it, off the banks of Newfoundland, and been in port a very considerable time before them, by keeping out of the stream; whereas they lengthened their passage by keeping in it. The general course of the Gulph stream being marked on the chart, I would advise those who make the northern passage from Europe, never to come nearer the inner line of it by choice than 10 or 15 leagues; and then the probability will be, that their passage will be assisted by the help of a counter current, which often runs within it. In coming off a voyage from the southward, be sure to steer NW when approaching the stream, if the wind will permit you, and continue that course until you are within it, which may be easily known by the temperature of the water, as before mentioned. I have always considered it of the utmost consequence when bound in, to cross the Gulph stream as speedily as possible, lest I should be visited by calms or adverse winds, and by that means drove far out of my way, which would prolong the voyage considerably, especially in the winter season."

B.

Extract from Sir George Staunton's account of an Embassy to China. Vol. 1, Eng. Ed. p. 88. Amer. Ed. p. 31.

"SIR Erasmus Gower observed that all ships bound from Europe for the island of Madeira, will discover that their way is influenced by a current or set, from the western ocean into the bay, formed between Ushant and Cape Finistere, and into the Mediterranean; and as well as his observations in five visits to Madeira could enable him to ascertain, such current should be estimated to set SE about 11 miles in 50 leagues."

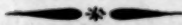
C.

Extract from Staunton's Embassy. Vol. 1, Eng. Ed. p. 88. Amer. Ed. p. 45.

"SIR Erasmus Gower observed in proceeding to Teneriffe a constant current setting to the southward, at the rate of a mile an hour, equal to 22 miles in the distance between that island and Madeira."

"Captain Mackintosh of the Hindostan, who had made twenty passages in this route, generally experienced a current from the 39th degree of latitude to that of the
Canaries.

Canaries. In this part of the ocean he formerly found from repeated and accurate observations, that this current set 3 degrees 50 minutes ESE. He found it strongest opposite to the entrance into the Mediterranean or straits of Gibraltar; and in one voyage the current was computed by his time keeper to set about 40 miles a-day. This current inclines more southerly as it approaches the Canaries. It strikes on the coast of Barbary and takes about Cape Bojador, different and opposite directions, near in shore one part running to the northward towards the Mediterranean, and the other to the southward along the coast towards the equator."



D.

Extracts from Kirwan's Estimate of the Temperature of different Latitudes.

"WE may observe, that the heat and cold of different countries are transmitted from one to the other by the medium of winds. How the air of a cold country is determined to flow towards a warmer, is easily understood; but by what means warm air is determined to flow towards cold countries, is somewhat difficult to explain. I shall here mention three causes that occur to me, wishing for a fuller explanation from others."

"First, if a strong northerly wind prevails in the direction of the meridian opposite to London, as in
the

the country of the Tschutshi, in the eastern extremity of Asia, this current must be supplied by air from the North Pole ; and this in its turn by air south of the Pole in the direction of the meridian of London."

" 2dly. If from any tract in the upper regions of the atmosphere, two currents of air flow in opposite directions, as sometimes happens, the inferior air being less compressed, will become specifically lighter ; and currents of air in opposite directions to the upper currents, will take place."

" 3dly. I conceive that when easterly and westerly winds meet with unequal force, one of them may be reflected northwards."

" SOME situations are better fitted to receive or communicate heat than other situations ; thus high and mountainous situations being nearer to the source of cold, must be colder than lower situations ; and countries covered with woods, as they prevent the access of the sun's rays to the earth, or to the heaps of snow which they may conceal, and present more numerous evaporating surfaces, must be colder than open countries, though situated in the same latitude ; and since all tracts of land present infinite varieties of situation, uniform results cannot here be expected. It remains then, that we seek for a standard situation, with whose temperature in every latitude we may compare and appreciate the temperature of all other situations in the same latitudes,

tudes, on water only. Now the globe contains, properly speaking, but two great tracts of water, or oceans: one, the Atlantic, separating Europe and the western side of the old continent from America; and the other, the Pacific, dividing Asia from America; both of which I divide into north and south, as they lie on the northern or southern side of the equator."

"In this immense tract of water I chose that situation for a standard, which recommends itself most by its simplicity and freedom from any but the most permanent causes of alteration, viz. that part of the Atlantic that lies between the 80th degree of northern and the 45th of southern latitude, and extending westwards as far as the Gulph stream,* and to within a few leagues of the coast of America; and all that part of the Pacific ocean, reaching from lat. 45°. N to lat. 40°. S, from the 20th to the 275th degree of longitude, east of London, which is by far the greater part of the surface of the whole globe. Within this space it will be found that the mean annual temperature is, as expressed in the following table. I have added the temperature of latitudes beyond 80 degrees in the northern hemisphere, though not strictly within the standard."

N

"TABLE

* Dr. Blagden, in an ingenious paper in the Philosoph. Transf. for 1781, has shewn that the temperature of this stream is considerably greater than that of the adjacent part of the Atlantic.†

† It was before discovered by Dr. Franklin, see journal on board of the Pennsylvania Packet, Capt. Osborne, in 1775, and on board of the Reprisal, Captain Wyke, in 1776.

*"TABLE of the Mean Annual Temperature of the
Standard situation, in every Latitude.*

Lat.	Temp.	Lat.	Temp.	Lat.	Temp.
90	31	61	43,5	32	69,1
89	31,04	60	44,3	31	69,9
88	31,10	59	45,09	30	70,7
87	31,14	58	45,8	29	71,5
86	31,2	57	46,7	28	72,3
85	31,4	56	47,5	27	72,8
84	31,5	55	48,4	26	73,8
83	31,7	54	49,2	25	74,5
82	32	53	50,2	24	75,4
81	32,2	52	51,1	23	75,9
80	32,6	51	52,4	22	76,5
79	32,9	50	52,9	21	77,2
78	33,2	49	53,8	20	77,8
77	33,7	48	54,7	19	78,3
76	34,1	47	55,6	18	78,9
75	34,5	46	56,4	17	79,4
74	35	45	57,5	16	79,9
73	35,5	44	58,4	15	80,4
72	36	43	59,4	14	80,8
71	36,6	42	60,3	13	81,3
70	37,2	41	61,2	12	81,7
69	37,8	40	62	11	82
68	38,4	39	63	10	82,3
67	39,1	38	63,9	9	82,7
66	39,7	37	64,8	8	82,9
65	40,4	36	65,7	7	83,2
64	41,2	35	66,6	6	83,4
63	41,9	34	67,4	5	83,6
62	42,7	33	68,3	0	84"

" WITH

" WITH respect to the annual temperature, we may remark : 1st. That within 10 degrees of the poles the temperatures differ very little ; neither do they differ much within 10 degrees of the equator."

" 2dly. The temperature of different years differ very little near the equator, but they differ more and more, as the latitudes approach the poles."

" 3dly. It scarce ever freezes in latitudes under 35° . unless in very elevated situations, and it scarce ever hails in latitudes higher than 60° .*"

" 4thly. Between latitudes 35° . and 60° . in places adjacent to the sea, it generally thaws when the sun's altitude is 40° . and seldom begins to freeze, until the sun's meridian altitude is below 40° ."

" IN every latitude, the mean temperature of the month of April, seems to approach very nearly, to the mean annual heat of that latitude ; and, as far as heat depends on the action of the solar rays, the mean heat of every month, is as the mean altitude of the sun, or rather, as the sine of the sun's mean altitude during that month."

" Hence the mean heat of April, and the sines of the sun's altitude being given, I find the mean heat of May, by this analogy. As the sine of the sun's mean altitude in April, is to the mean heat of April, so is the

* 9 Vet. Com. Petrob.

the sine of the sun's mean altitude in May, to the mean heat of May. In this manner, I find the temperatures of June, July and August: But this rule would give the temperatures of the succeeding months much too low; because, it does not comprehend the quantity of heat accruing to the atmosphere by communication of the internal heat of the globe, which in every latitude is nearly the same, as the mean annual heat of that latitude. Hence, the real temperature of these months, must be looked upon as an arithmetical mean, between the astronomical, and terrestrial heats. Thus, in lat. 51° . the astronomical heat of the month of September, is $44^{\circ}.66$, and the mean annual heat is $52^{\circ}.4$; therefore, the real mean heat of this month, should be $\frac{44.6 + 52.4}{2} = 48.4$, which is more conformable to observation."

"It may indeed be said, that not only the sun's altitude in every month, but also the duration of its light over the horizon, should be taken into consideration. And, without doubt, this, and some other circumstances taken into account by Mr. De Mairan, should not have been omitted by me, if all the circumstances productive of cold, could also be subjected to calculation; but some of these can no way be estimated; for instance, the cold produced by evaporation: therefore, by way of compensation, some of those productive of heat, should also be omitted; and in effect, the approximation of the calculated, to the real heat, is much

much greater when this element is left out. Thus the temperature of June in lat. 51° . including this circumstance, is 70° .; whereas, in fact, the mean heat of June, in London, is only 63. nor does it exceed 66° . even at Paris, lat. 48° . $50'$. However, after going through a tedious calculation, I still found the results to agree but ill with observation; and therefore, the ensuing table, is not to be looked upon as deduced from fixed principles, but rather partly from principles, and partly from what appeared to me, after studying a variety of sea journals, most conformable to observation. And, as a table of the mean monthly temperatures of different latitudes at sea, can never be had by observation, I flatter myself that such a table as this, made as correct as the nature of things will allow, may in some measure supply its place."

"From this Table we may learn,

1st. To find the mean heat of the first, and last half of any month."

"Find the mean betwixt the standard heat of any month, and the standard heat of the succeeding; this will be the mean of the last fifteen days of the preceding, and the first fourteen or fifteen days of the succeeding month."

"2dly. To find the usual extremes whether of heat, or of cold, that take place in any month."

"Find

“ Find the difference of the monthly and annual temperatures; this difference *added* to the monthly temperature, gives the temperature of the hottest day, that is usually found in any month; or being *subtracted* gives the coldest day, usually observed within the month: By day, I mean the space of twenty-four hours. Thus in London, the annual temperature being 52° . and the temperature of January 36° . the difference is 16, consequently the warmest day in January is 52° . and the coldest 20° .”

“ The greatest cold within the twenty-four hours, generally happens half an hour before sun rise, in all latitudes. The greatest heat in all latitudes between 60° . and 45° . is found about half past two o'clock in the afternoon; between lat. 45° . and 35° . at two o'clock; between lat. 35° . and 25° . at half past one; and between lat. 25° . and the equator, at one o'clock.”

“ On sea, the difference between the heat of day and night, is not so great as on land, particularly in low latitudes.”

“ The coldest weather in all climates, generally prevails about the middle of January, and the warmest in July, though, astronomically speaking, the greatest cold should be felt at the latter end of December, and the greatest heat in the latter end of June; but the earth requires some time to take, or to lose the influence of the sun, in the same manner as the sea with respect to tides, does that of the moon.”

“ TABLE

NOTES.

91

TABLE of the Monthly Mean Temperature of the Standard, from lat. 80°. to lat. 10°.

Latitude	80°	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°	69°	68°	67°	66°	65°	64°	63°
January	22,	22,5	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	27,5	28,	28,	28,	29,	30,
February	23,	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	28,	28,	28,5	29,	30,	31,	32,
March	27,	27,5	28,	28,5	29,	29,5	30,	30,5	31,	31,5	32,	32,5	33,	33,5	34,	35,	36,	37,
April	32,6	32,9	33,2	33,7	34,1	34,5	35,	35,5	36,	36,6	37,2	37,8	38,4	39,1	39,7	40,4	41,2	41,9
May	36,5	36,5	37,	37,5	38,	38,5	39,	39,5	40,	40,5	41,	41,5	42,	42,5	43,	44,	45,	46,
June	51,	51,	51,5	52,	52,	52,	52,5	53,	53,5	54,	54,	54,5	54,5	54,5	55,	55,	55,5	55,5
July	50,	50,	50,5	51,	51,	51,	51,5	52,	52,5	53,	53,5	53,5	53,5	54,	54,5	54,5	55,	55,
August	39,5	40,	41,	41,5	42,	42,5	43,	43,5	44,	44,5	45,	45,5	46,	47,	48,	48,5	49,	50,
Septem.	33,5	34,	34,5	35,	35,5	36,	36,5	37,	38,	38,5	39,	39,5	40,	41,	42,	43,	44,	45,
October	28,5	29,	29,5	30,	30,5	31,	31,5	32,	32,5	33,	33,5	34,	34,	35,	36,	37,	37,5	38,
Novem.	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	28,	28,5	29,	30,	31,	32,	32,5	33,
Decem.	22,5	23,	23,5	24,	24,5	25,	25,5	26,	26,5	27,	27,5	28,	28,	29,	30,	30,5	31,	31,

NOTES.

Latitude	62°	61°	60°	59°	58°	57°	56°	55°	54°	53°	52°	51°	50°	49°	48°	47°	46°
January	31,	32,	33,	34,	35,	36,	37,	38,	39,	40,	41,	42,	42,5	42,5	43,	43,5	44,
February	33,	34,	35,	36,	37,	38,	39,	40,	41,	42,	43,	44,	44,5	44,5	45,	45,5	46,
March	38,	39,	40,	41,	42,	43,	44,	45,	46,	48,	49,	50,	50,5	51,	52,5	53,	53,5
April	42,7	43,5	44,3	45,09	45,8	46,7	47,5	48,4	49,2	50,2	51,1	52,4	52,9	53,8	54,7	55,6	56,4
May	47,	48,	49,	50,	51,	52,	53,	54,	55,	56,	57,	58,	58,5	59,	60,	61,	62,
June	56,	56,	56,	56,5	57,	57,	57,5	58,	58,5	59,	59,	60,	61,	62,	63,	64,	65,
July	55,5	55,5	56,	56,5	57,	57,5	58,	59,	60,	61,	62,	63,	63,5	64,	65,	66,	67,
August	51,	52,	53,	54,	55,	56,	57,	58,	59,	60,	61,	62,	63,5	64,	65,	66,	67,
Septem.	46,	47,	48,	49,	50,	51,	52,	53,	54,	55,	56,	57,	58,5	59,	60,	61,	62,
October	39,	40,	41,	42,	43,	44,	45,	46,	47,	48,	49,	50,	50,5	51,	52,	53,	54,
Novem.	34,	35,	36,	37,	43,	39,	40,	41,	42,	43,	44,5	46,	46,5	47,	48,	49,	50,
Decem.	32,	33,	34,	35,	36,	37,	38,	39,	40,	41,	42,	44,	44,5	45,	46,	47,	48,

Latitude	45°	44°	43°	42°	41°	40°	39°	38°	37°	36°	35°	34°	33°	32°	31°	30°	29°	28°
January	44.5	45	45.5	46	46.5	49.5	51	52	53.5	55	56.5	59.5	63	63	63	63.5	63.5	63.5
February	46.5	47	48	49	50	53	56.5	58	60	61	62	63	64.5	66	67	68.5	68.5	69.5
March	54.5	55.5	56.5	58.5	59.5	60	60.5	61	62	63	64	65	66.5	67.5	68.5	69.5	71	72
April	57.5	58.4	59.4	60.3	61.2	62.1	63	63.9	64.8	65.7	66.6	67.4	68.3	69.1	69.9	70.7	71.5	72.3
May	63	64	65	66	67	68	69	70	70.5	71	71.5	72	72.5	73	73	73.5	74.5	75.5
June	65	67	68	69	70	70.5	71	71	71	71.5	71.5	72	72.5	73	73	73.5	74.5	75.5
July	68	69	69.5	70	70	71	71	72	72	72.5	72.5	72.5	72.5	73	73	73.5	74.5	75.5
August	68	69	69.5	70	70	71	71	72	72	72.5	72.5	72.5	72.5	73	73	73.5	74.5	75.5
Septem.	63	64	66	68	69.5	70.5	71	71.5	72	72.5	72.5	72.5	72.5	73	73	73.5	74	75.5
October	55	56	57	58	59	60	61	62	63	64	65	66	67.5	68.5	69.5	70.5	71	72.5
Novem.	51	52	53	54	55	56	57	58	59	60	61	62	63	64.5	65.5	66.5	68	69
Decem.	49	50	51	52	53	54	55	56	57	58	59	60	61	62.5	63.5	64.5	66	67

Latitude	27°	26°	25°	24°	23°	22°	21°	20°	19°	18°	17°	16°	15°	14°	13°	12°	11°	10°
January	64,	64,5	65,5	67,	68,	69,	71,	72,	72,5	73,	73,5	74,	74,5	75,	76,	76,5	77,	77,5
February	69,5	70,5	71,	62,	72,	72,5	74,	75,	76,	76,5	77,	77,5	78,	78,5	79,	79,5	79,8	80,
March	72,5	73,	73,5	74,5	75,	75,5	76,	77,	77,5	78,	78,5	79,	79,5	80,	80,8	81,	81,5	81,8
April	72,8	73,8	74,5	75,4	75,9	76,5	77,2	77,8	78,3	78,9	79,4	79,9	80,4	80,8	81,3	81,7	82,	82,3
May	76,	76,5	77,5	78,	78,5	79,5	80,	80,5	81,	81,5	82,	82,5	83,	83,	83,5	84,	84,	84,3
June	76,	76,5	78,	78,5	79,	79,5	80,	80,5	81,5	82,	82,5	83,	83,5	83,8	84,	84,3	84,6	84,8
July	76,	76,5	78,	78,5	79,	79,5	80,	80,5	81,5	82,	82,5	83,	83,5	83,8	84,	84,3	84,6	84,8
August	76,	76,5	78,	78,5	79,	79,5	80,	80,5	81,5	82,	82,5	83,	83,5	83,8	84,	84,3	84,6	84,8
Septem.	76,	76,5	77,5	78,	78,5	79,	79,5	80,	81,	81,5	82,	82,5	83,	83,	83,5	84,	84,3	84,6
October	72,5	73,	73,5	74,5	75,	75,5	77,	78,	79,	80,	81,	81,5	82,	82,5	83,	83,5	83,8	84,
Novem.	69,5	71,5	72,	73,5	74,	74,5	75,	75,5	76,	77,	78,	78,5	79,	79,5	80,	80,5	80,8	81,
Decem.	67,5	68,5	69,5	70,5	71,	71,5	72,	72,5	73,	74,	75,	75,5	76,	76,5	77,	77,5	78,	78,



TEMPERATURE OF THE SEA.

N. lat.		Heat at the Surface.	Depth. Feet.	Heat.
70°	May 12	36°	502	39
	17	37°	540	39
	June 9	44°	558	40
	July 7	46°	420	44
68°	8	47°	1560	52
65°	9	48°	1280	48
	10	52°	846	45 *
27°	Jan. 3	64°	540	58 †
0		84°	3600 & } 5346 }	53 †

* Phil. Tr. 1770, p. 39.

† 2 Bergm. Erde Kugel, p. 119.

‡ Phil. Tr. 1752, p. 213.

“ But Lord Mulgrave found the temperature of the sea, at great depths, in high latitudes, much colder; he does not indeed mention, the temperature of the surface, but it is presumed, it did not differ much from that of the air; perhaps the reason was, that the newly melted ice, had then descended, though the first experiment cannot be explained, even on that hypothesis.

Lat. N.		Heat of Air.	Depth.	Heat of the Sea.
67°	June 20	48°.5	4680	26°
78°	30	40°.5	708	31°
69°	Aug. 31	59°.5	4038	32°

Observations

Observations of Messrs. Wales and Bayley.

Lat.		Air.	Surface.	Depth. Feet.	Heat of the Sea.
0	Sept. 5	75°.5	74°	510	66°
24 S	26	72°.5	70°	480	70°
34.44'	Oct. 11	60°.5	59°	600	57°

Observations of Mr. Bladh.*

57° N	Jan. 8	46°	37°	6	40°
	10	43°.6	43°.6	50	43°.6
55°.40	20	47°	40°	110	51°.5
39°.30	28	53°	59°	110	59°
2°.55	Feb. 25	84°	81°	58	81°
2°.50	26	83°	84°.5	110	81°

* Suenk. Handling. 1781.

E.

IN the foregoing extract it is said that in lat. 67°. at the depth of 4680 feet, Lord Mulgrave found the temperature of the sea water at 26°. which is 6°. below the freezing point. This is a seeming contradiction. But it may be considered that 32°. is the point of the slightest congelation in river water. Sea water freezes with more difficulty because the salt must first be separated, for at the surface all ice is fresh.

The hypothesis intimated in the introduction to this work proceeds upon the principle, that although the ice formed at the surface of the sea is always fresh, yet a degree

degree of cold may happen which would make *salt ice*; or, in other words, a degree of cold may occur which would precipitate the salt, and combine it with ice. We know that the Academicians at Peterf-burg, in 1759, by means of snow and nitre reduced the mercury in a thermometer to a solid state, which bore the compression of the hammer. What fluid could resist congelation longer than mercury? Hence, by the conjecture that the bottom of the sea is ice, it is intended to convey an idea of much colder ice, than such as our winters produce.

F.

METHOD of comparing Fahrenheit's thermometer with that of Reaumer, so that either instrument may answer for nautical use.

N. B. The freezing point by Fahrenheit's scale is 32° . by Reaumer's it is 0.

It requires nine degrees on Fahrenheit's scale to make four on Reaumer's, therefore to graduate an instrument according to both, observe this rule :

From any given degree of Fahrenheit deduct the freezing point 32° . then divide the remainder by nine, and afterwards multiply this ninth part or quotient by four and the answer will be degrees according to Reaumer.

To reverse this operation—Divide any given degree of Reaumer by four, and multiply the quotient or fourth part by nine, to the product add 32 . the freezing point and the answer will be degrees according to Fahrenheit:

EXAMPLE.

Take Fahrenheit's degree of	122°
Deduct the freezing point,	32
Divide this by nine,	90
Quotient,	10
Multiply this $\frac{1}{9}$ th part by	4
An equivalent degree of heat by Reaumer,	40

REVERSE.

Take Reaumer's degree of	40°
Divide this by 4,	
Quotient,	10
Multiply this $\frac{1}{4}$ th part by	9
Product,	90
Add the freezing point,	32
An equivalent degree of heat by Fahrenheit,	122°

ERRATA.

Introduction, page 10, line 2d, for "at 32°. and must not that be ice?" read *below* 32°. and *may* not that be ice?

Page 48, line 18, for "perpendicularly" read *vertical*.

Page 53, line 6, for "unobserved," read *unobserved*.



POSTSCRIPT.

The foregoing part of this work was printed before any communication could be made to Capt. Truxton on the subject; and the whole was sent to press before the letter, of which the following is an extract, came to hand.

As experiment is the only proper test of usefulness, and as the opinion of a well known nautical character is more likely to inspire confidence among navigators than any thing the writer himself could say; the motive for adding this postscript becomes too strong to be resisted.

Extract of a Letter from THOMAS TRUXTON, Esq.
to JONATHAN WILLIAMS.

“ *Perth Amboy, 12th Aug. 1799.*

“ *YOUR publication will be of use to navigation, by rendering sea voyages secure, far beyond what even you yourself will immediately calculate, for I have proved the utility of the thermometer very often since we sailed together, not only in crossing and re-crossing the Gulph stream that runs along our coasts, but in the Ethiopian, Indian, Arabian and Chinese seas, gulph of Bengal, gulph of Siam, the various straits in the eastern world, and in many other parts of the globe.*

“ *It*

“ It will be found a most valuable instrument in the hands of mariners, and particularly so to those who are unacquainted with astronomical observations, and calculations for determining the longitude at sea ; these particularly stand in need of a simple method of ascertaining their approach to, or distance from the coast, especially in the winter season ; for it is then that passages are often prolonged, and ships blown off the coast, by hard westerly winds, and vessels being in the Gulph stream, without its being known ; on which account they are often hove too, by the Captain’s supposing themselves near to the coast, when they are very far off, and by this means favorable spirits of wind are lost : On the other hand ships are often cast on the coast by sailing in the eddy of the stream, which causes them to out-run their common reckoning : Every year produces new proofs of these facts, and of the calamities incident thereto.”

✂ Should a second edition appear proper, it is hoped that the writer will have it in his power to add not only these communications, but the experiments of many other Navigators. With this view, and in the mean time to prevent erroneous editions, the copyright to this work is secured according to law.

J. W.

DISTRICT OF PENNSYLVANIA—*To wit:*

BE it remembered, THAT on the ninth day of August, in the twenty-fourth year of the Independence of the United States of America, JONATHAN WILLIAMS, of the said district hath deposited in this office the title of a book, the right whereof he claims as AUTHOR, in the words following, *to wit:—*

“ THERMOMETRICAL NAVIGATION.

“ *Being a series of experiments and observations, tending*
“ *to prove, that by ascertaining the relative heat of the sea*
“ *water from time to time, the passage of a ship through*
“ *the Gulph stream, and from deep water into soundings,*
“ *may be discovered in time to avoid danger, although*
“ *(owing to tempestuous weather) it may be impossible to*
“ *heave the lead or observe the heavenly bodies. Extracted*
“ *from the American Philosophical Transactions, vol. 2*
“ & 3. *With additions and improvements.—*

“ God helps them that help themselves.”

“ *Poor Richard.*”

In conformity to the act of the congress of the United States, intituled “ An Act for the encouragement of learning by securing the copies of maps, charts and books to the authors and proprietors of such copies during the times therein mentioned ”

D. CALDWELL,

Clerk of the district of Pennsylvania.

